Indian Head Division
Naval Surface Warfare Center
Indian Head, MD 20640-5035

IHTR 2922
28 July 2008

QUALIFICATION OF TRIVALENT CHROMATE AS A HEXAVALENT CHROMATE ALTERNATIVE FOR PROPELLANT AND CARTRIDGE ACTUATED DEVICES

Harry L. Archer

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE (DD-MM-YYYY)	2. REPORT TYPE	3. DATES COVERED (From - To)
28 July 2008	Final Report	

4. TITLE AND SUBTITLE

QUALIFICATION OF TRIVALENT CHROMATE AS A HEXAVALENT CHROMATE ALTERNATIVE FOR PROPELLANT AND CARTRIDGE ACTUATED DEVICES

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

Harry L. Archer

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Indian Head Division
Naval Surface Warfare Center
Indian Head, MD 20640-5035

8. PERFORMING ORGANIZATION REPORT NUMBER

IHTR 2922

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

A low toxicity trivalent chromate conversion coating (TCP) over a zinc-phosphate conversion coat was qualified to replace toxic hexavalent chromate conversion coating (CCC) on zinc-nickel plated steel. Unpainted test panels exhibited at least 42 days of resistance to cyclic salt fog. These panels lasted at least 4 days when subjected to cyclic sulfur dioxide and cyclic salt fog testing with full red rust evident on the seventh day. Painted and scored TCP panels previously subjected to 10 days of humidity and 120 days of salt cyclic fog were subject to 78 days of cyclic sulfur dioxide and salt fog. This paint was still largely intact with only moderate score corrosion and paint blistering near the score. Breakaway torque required to unscrew adhesively bonded TCP over zinc-phosphate conversion coated zinc-nickel plated exceeded their initial assembly torque on representative propellant actuated device and cartridge actuated device parts.

15. SUBJECT TERMS

Hexavalent chromate alternative
Propellant actuated devices
Cartridge actuated devices
trivalent corrosion plating plating coating conversion

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
U	U	U	SAR	59	Susan Simpson
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FOREWORD

The work reported herein was performed at the Indian Head Division, Naval Surface Warfare Center, Indian Head, MD.

John L. Goodwin
Manager, Propellant Actuated
Devices Development Branch

Approved and released by:

Phillip R. Sturgill
Director, CAD/PAD Engineering Division

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ACKNOWLEDGMENTS

I give special thanks to:

- Diane Sabal and Paul McCafferty both of Naval Surface Warfare Center, Indian Head Division (IHDIV/NSWC), (sponsors)

- John Goodwin, IHDIV/NSWC and Craig Pfleegor, IHDIV/NSWC, (management)

- Daniel Sorensen, IHDIV/NSWC, (compatibility testing)

- Wayne J. Powell, Polyplex Corporation, (technical advisors),

- Craig Matzdorf, Naval Air Station, Patuxent River, (TCP co-inventor)

- Jeff Adams, AMZ plating (plating)

- George Hollen, and Zelda Brown, (procurement) IHDIV/NSWC

- Mark Dembinsky (torque testing), IHDIV/NSWC; Andrew Sheetz and Dan Davis (cyclic salt fog testing), and Graig Jolley (chip resistance), NSWC Carderock Division; Andy S. Schwartz, (cyclic sulfur dioxide/salt fog testing); NAVAIR Patuxent River

- Fred Zimmerman, (patent support), IHDIV/NSWC.

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INTRODUCTION

On February 28th, 2006, the Occupational Safety and Health Administration changed the permissible exposure limit for hexavalent chromate[1,2] *from 52 to 5μgrams per cubic meter*. This change came *after* IHDIV/NSWC qualified a hexavalent chromate conversion coating (CCC) for use on unpainted PADs. This new requirement will make hexavalent chromated products difficult to procure in the near future.

Testing described herein qualifies a non-proprietary trivalent chromate (also known as TCP) (Figure 3) over zinc-phosphate coating system to replace hexavalent chromate on zinc-nickel plated carbon steel PADs and CADs. We previously tested and qualified a zinc-nickel plating system (see IHTR 2694[3]). These include:

- hexavalent chromate on zinc–nickel
- primed/painted hexavalent chromate on zinc–nickel,
- primed/painted TCP over zinc-phosphate on zinc–nickel.

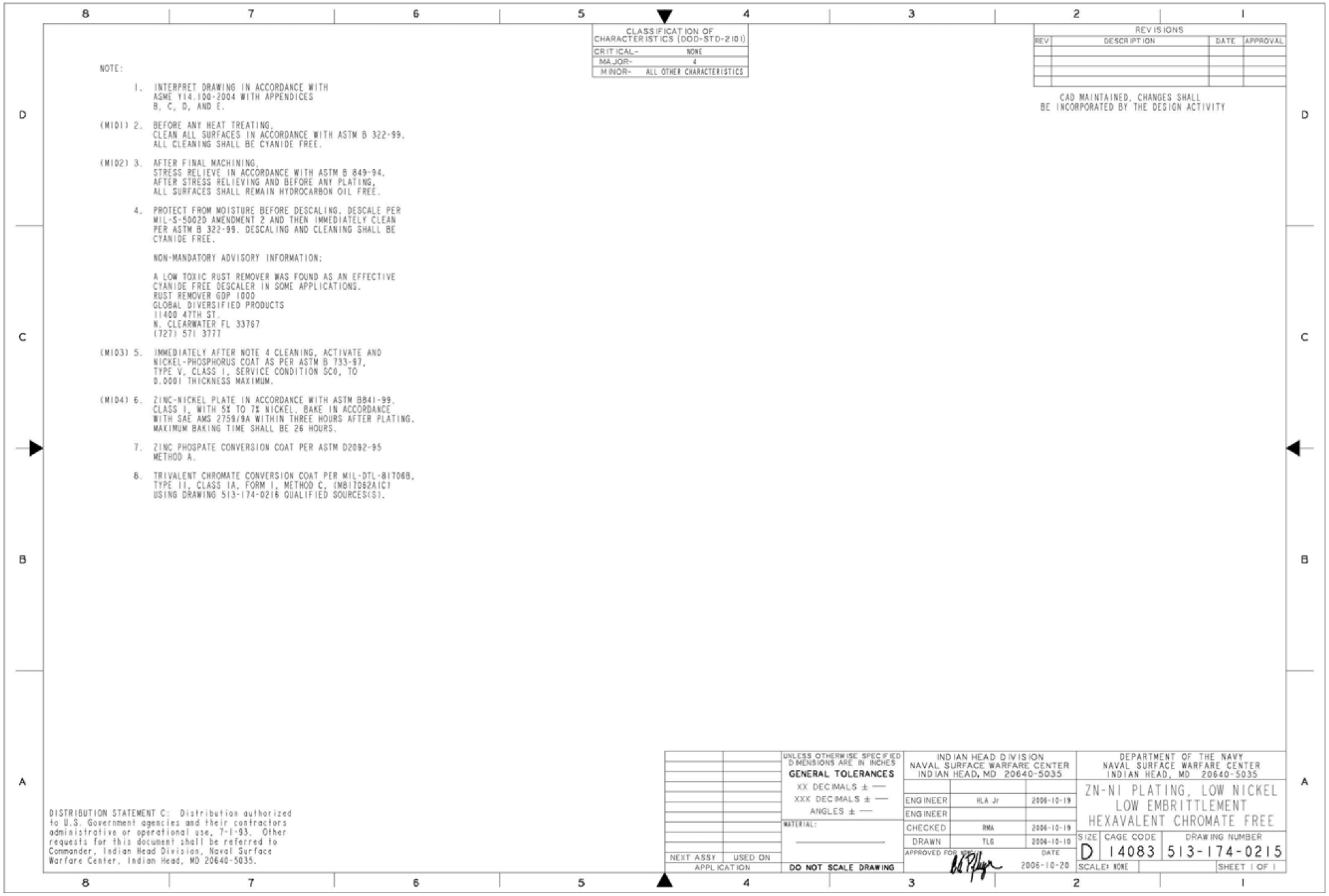
However, IHDIV/NSWC did not previously test unpainted TCP over zinc-phosphate on zinc–nickel. The photo in the bottom of Table VIII in IHTR 2694[3] shows no corrosion, even in the score on the bottom of the painted TCP test panel. Therefore, only limited testing is required to qualify this TCP plating system. Moreover, unpainted TCP weren't previously tested for gravel resistance.

Often CADs have more exposure to marine and shipboard smoke stack sulfur dioxide emissions than PADs, therefore testing for this type environment would be useful.

Plating typically changes the torque retaining power of threads. Adhesives used to lock thread in place often lubricate threads to facilitate assembly. Therefore, it is useful to determine if this new plating adversely affect the holding power of the torqued thread.

OBJECTIVE

IHDIV/NSWC's objective is to qualify plating (Figure 1) 513-174-0215, *Zinc-Nickel Plating, Low Nickel, Low Embrittlement, Hexavalent Chromate Free* and a higher nickel version (12 percent versus 5 percent) (Figure 2) SK07005-E213K-2 for steel unpainted shipboard/marine propellant actuated devices (PADs), cartridge actuated devices (CADs) environments. We also desire to establish the durability of steel plated in accordance with drawing 513-174-0215 and a higher nickel (12 percent versus 5 percent) version of SK07005-E213K-1 (Figure 2) to withstand shipboard smokestack sulfur/sulfuric acid and salt fog emissions.



CLASSIFICATION OF CHARACTERISTICS (DOD-STD-2101)	
CRITICAL-	NONE
MAJOR-	4
MINOR-	ALL OTHER CHARACTERISTICS

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(M102) 3. AFTER FINAL MACHINING. STRESS RELIEVE IN ACCORDANCE WITH ASTM B 849-94. AFTER STRESS RELIEVING AND BEFORE ANY PLATING, ALL SURFACES SHALL REMAIN HYDROCARBON OIL FREE.

4. PROTECT FROM MOISTURE BEFORE DESCALING. DESCALE PER MIL-S-5002D AMENDMENT 2 AND THEN IMMEDIATELY CLEAN PER ASTM B 322-99. DESCALING AND CLEANING SHALL BE CYANIDE FREE.

NON-MANDATORY ADVISORY INFORMATION:

A LOW TOXIC RUST REMOVER WAS FOUND AS AN EFFECTIVE CYANIDE FREE DESCALER IN SOME APPLICATIONS.
RUST REMOVER GDP 1000
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N. CLEARWATER FL 33767
(727) 571 3777

(M103) 5. IMMEDIATELY AFTER NOTE 4 CLEANING, ACTIVATE AND NICKEL-PHOSPHORUS COAT AS PER ASTM B 733-97, TYPE V, CLASS 1, SERVICE CONDITION SC0, TO 0.0001 THICKNESS MAXIMUM.

(M104) 6. ZINC-NICKEL PLATE IN ACCORDANCE WITH ASTM B841-99, CLASS 1, WITH 5% TO 7% NICKEL. BAKE IN ACCORDANCE WITH SAE AMS 2759/9A WITHIN THREE HOURS AFTER PLATING. MAXIMUM BAKING TIME SHALL BE 26 HOURS.

7. ZINC PHOSPATE CONVERSION COAT PER ASTM D2092-95 METHOD A.

8. TRIVALENT CHROMATE CONVERSION COAT PER MIL-DTL-81706B, TYPE II, CLASS 1A, FORM 1, METHOD C, (M817062A1C) USING DRAWING 513-174-0216 QUALIFIED SOURCES(S).

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ZN-NI PLATING, LOW NICKEL
LOW EMBRITTLEMENT
HEXAVALENT CHROMATE FREE

SIZE	CAGE CODE	DRAWING NUMBER
D	14083	513-174-0215

SCALE: NONE | SHEET 1 OF 1

Figure 1. Zinc-Nickel Plating, Low-Nickel, Low Embrittlement, Hexavalent-Chromate Free (ID 12)[5,6,7,8,9,10,11,12,13]

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(M103) 5. IMMEDIATELY AFTER NOTE 4 CLEANING, ACTIVATE AND NICKEL-PHOSPHORUS COAT AS PER ASTM B 733-97, TYPE V, CLASS 1, SERVICE CONDITION SC0, TO 0.0001 THICKNESS MAXIMUM.

(M104) 6. ZINC-NICKEL PLATE IN ACCORDANCE WITH SAE AMS 2417G, TYPE 3, WITH 9% TO 13% NICKEL (12% NOMINAL). BAKE IN ACCORDANCE WITH SAE AMS 2759/9A WITHIN THREE HOURS AFTER PLATING. MAXIMUM BAKING TIME SHALL BE 26 HOURS.

7. ZINC PHOSPATE CONVERSION COAT PER ASTM D2092-95 METHOD A.

8. TRIVALENT CHROMATE CONVERSION COAT PER MIL-DTL-81706B, TYPE II, CLASS 1A, FORM 1, METHOD C, (M81706 2A1C) USING DRAWING 513-174-0216 QUALIFIED SOURCES(S).

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ZN-NI PLATING, HIGH NICKEL, LOW EMBRITTLEMENT, HEXAVALENT CHROMATE FREE

SIZE	CAGE CODE	DRAWING NUMBER
D	14083	SK07005-E213K-2
SCALE: NONE		SHEET 1 OF 1

Figure 2. Zinc-Nickel Plating, High-Nickel, Low Embrittlement, Hexavalent-Chromate Free (ID 12x)[5,6,7,8,9,14,12,13]

4

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3CLE7	METALAST INTERNATIONAL, INC. METALAST TECH CENTER 2241 PARK PLACE MINDEN, NEVADA 89423 (775) 782-8324	TCP-HF	ZINC PHOSPHATED SURFACES
55053	LUSTER-ON PRODUCTS INC. 54 WALTHAM AVE SPRINGFIELD, MA 01109 (800) 888-2541 X126	ALUMINESCENT	
1N6B3	HENKEL SURFACE TECHNOLOGIES 32100 STEPHENSON HWY. MADISON HEIGHTS, MI 48071 (248) 577-2126	ALODINE T5900	
1YPM7	CST-SURTEC 6801 ENGLE ROAD, SUITE J PO BOX 81873 CLEVELAND, OH 44181 MIDDLEBURG HEIGHTS, OH 44130 (973) 243-1773	CHROMITAL TCP SURTEC 650	

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TRIVALENT CHROMATE CONVERSION COATING

SIZE	CAGE CODE	DRAWING NUMBER
D	14083	513-174-0216
SCALE: NONE		SHEET 1 OF 1

Figure 3. Trivalent Chromate Conversion Coating

APPROACH

Test Panel Environmental Testing: Salt Fog and Chip Resistance Testing

Salt fog and chip resistance testing were both performed at Naval Surface Warfare Center, Carderock Division using the same equipment used to test panels qualified in IHTR 2694[3]. Sulfur dioxide testing was performed at NAVAIR Patuxent River.

Test Article

Panels were fabricated in accordance with 5130K-CAD-REPL-0100 (see Figure 4). These panels used the same steel roll stock as the ones used in IHTR 2694[3] and the low volatile organic content paint system[4] qualification. Moreover, all these test panels were the same configuration except the unpainted controls, which were larger, flat, and not from this steel stock.

Preparation

Panels were plated in accordance with Table I.

Testing

Panels were exposed to Table II cyclic salt fog testing. This is the same cyclic salt fog testing used to qualify the PAD paint system[4].

Torque Testing

We also compared the torque required to unscrew typical plated PAD and CAD items bonded with Eccobond® 45, Catalyst 15 (Figure 5) to assure that the coating does not significantly contribute to the loss of bonded screwed joint holding torque.

PADs

Test Article

There are many types of PAD parts. The Mk 74 underseat rocket motor (USRM) with its many threaded surfaces should be a good representation of threaded PADs.

Preparation

The Mk 74 is no longer a production item, so the igniter threads were trimmed, shown in Figure 6, to prevent them from reentering production.

The USRM and associated motor tubes (Figure 7), were plated according to Table III and assembled in accordance with Figure 8 with the same plating. All torque test items were from reworked parts. Therefore, they were stripped and plated according to 513-174-0213 (Figure 10) and SK07005-E213K-1 (Figure 11).

Testing

All assemblies were allowed to cure for at least 1 week. Afterwards, the tubes were unscrewed from the bodies with a torque wrench and the torque at first movement was recorded.

CADs

Test Article

MC 50 initiator steel body with aluminum M720 initiator heads represents typical CADs. This CAD was chosen because the parts were readily available and they have established torque test procedures.

Preparation

The bodies were plated according to Table III, and assembled according to Figure 9.

All torque test items were from reworked parts. Therefore, they were stripped and plated according to 513-174-0213 (Figure 10) and SK07005-E213K-1 (Figure 11).

Testing

All assemblies were allowed to cure for at least 1 week. Afterwards, the tubes were unscrewed from the bodies with a torque wrench and the torque at first movement was recorded.

Compatibility

As with any new coating, its compatibility must be considered if it is in contact with or outgases to propellant. Samples Mechanite 19 propellant were tested with samples of TCP to assess whether or not the TCP makes the propellant more reactive.

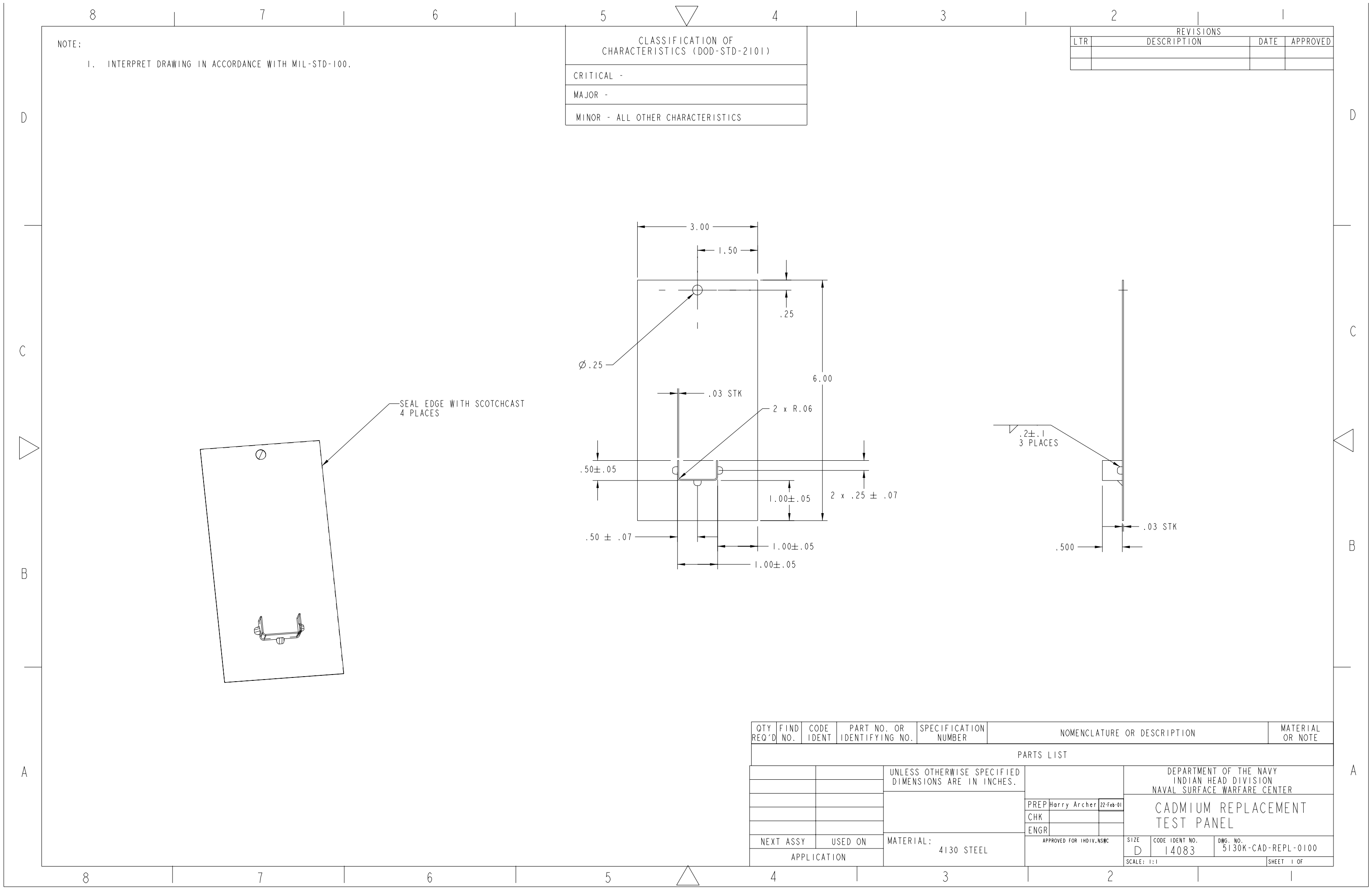


Figure 4. Test Panel Configuration

Table I. Test Panel Plating Preparation

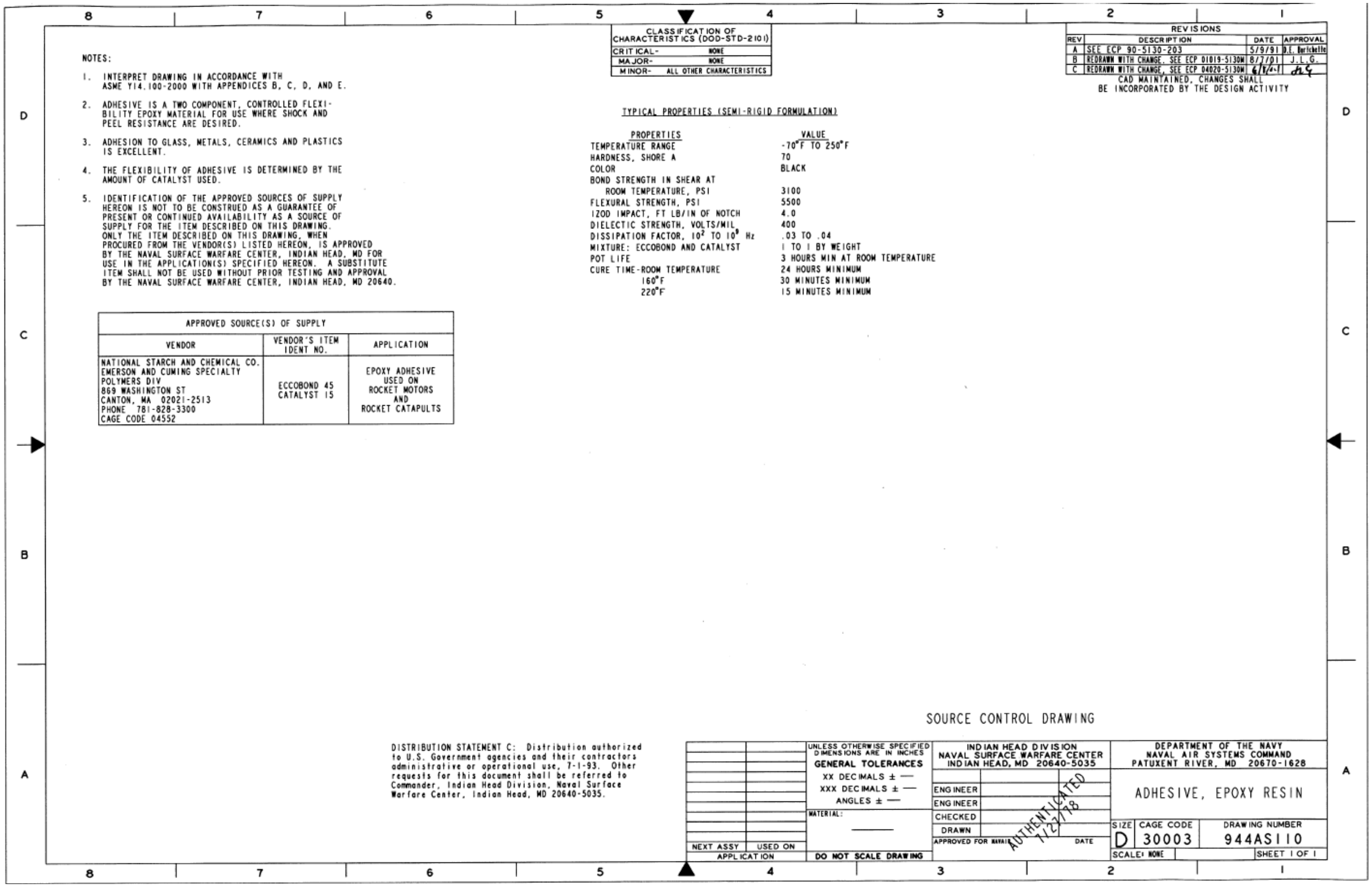
Item No.	Qty	Preparation Description for Drawing SK5130K-CAD-REPL-0100 (Figure 4)
12	9	1. Mark the number “12” (no quotes) on a corner near the ¼ in hole. 2. Plate panel in accordance with drawing 513-174-0215 (Figure 1).
12x	8	1. Mark the number “12x” (no quotes) on a corner near the ¼ in hole so that the item number can be seen after finishing. 2. Plate panel in accordance with drawing SK07005-E213K-1 (Figure 2).
Control	6	4 ½ in x 6 in 4130 Steel panels without weldment or plating
6p2* Reference only	6	1. Mark the number “6p2” (no quotes) on a corner near the ¼ in hole so that the item number can be seen after finishing. 2. Plate panel in accordance with drawing 513-174-0215. 3. Prime and paint as per MIL-DTL-85097[15]. Primer coating shall be per MIL-P-53030[16]. Paint shall be as per MIL-PRF-85285[17], Color, Gloss White No. 17935 in accordance with FED-STD-595[18].

* Note: The 6p2 panels were previous subjected to 10 day humidity per ASTM D2247-99[19], and MIL-P-83126A[20], Section 4.4.2.14.2 and 120 day salt fog per ASTM G85 ANNEX 5[21]. Each panel has been scored diagonally in an “X” pattern on the side opposite the channel. Also, the paint adhesion was tested.

Table II. Hexavalent Chromate Replacement Panel Test Matrix

Tests	Zinc – Nickel with Trivalent Chromate Conversion			
	Unpainted			Painted (panel ID #6p2 from test in IHTR 2694 pp 20)
Drawing SK5130K-CAD-REPL-0100 Panel Plated Per 513-174-0215 or 513-174-0213 if Reworked				
Rain test[h]	ID# 12, Qty 3	ID# 12x, Qty 3		
Humidity[i] test	Use the same panels used in “h” above	Use the same panels used in “h” above		
Salt fog[j]	Use the same panels used in “i” above	Use the same panels used in “i” above		
Chip resistance[k]		ID# 12, Qty 3	ID# 12x, Qty 3	
Salt fog[n] SO_2		ID# 12, Qty 3	ID# 12x, Qty 3	ID# 6p2, Qty 6

[h] MIL-P-83126A[20], Section 4.4.2.14.1
[i] ASTM D2247-99[19], and MIL-P-83126A[20], Section 4.4.2.14.2
[j] ASTM G85[21] ANNEX 5, 168hours and 1000hours (2000 & 3000 hours optional)
[k] ASTM D3170-03[22]
[n] ASTM G85[21] Annex A4 Section A4.4.4.1 Salt/SO_2 Spray (Fog) Testing.



CLASSIFICATION OF CHARACTERISTICS (DOD-STD-2101)

CRITICAL-	NONE
MAJOR-	NONE
MINOR-	ALL OTHER CHARACTERISTICS

REVISIONS

REV	DESCRIPTION	DATE	APPROVAL
A	SEE ECP 90-5130-203	5/9/91	D.E. Bartchelle
B	REDRAWN WITH CHANGE, SEE ECP 01019-5130M	8/7/01	J.L.G.
C	REDRAWN WITH CHANGE, SEE ECP 04020-5130M	6/8/04	JLG

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NOTES:

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2. ADHESIVE IS A TWO COMPONENT, CONTROLLED FLEXIBILITY EPOXY MATERIAL FOR USE WHERE SHOCK AND PEEL RESISTANCE ARE DESIRED.
3. ADHESION TO GLASS, METALS, CERAMICS AND PLASTICS IS EXCELLENT.
4. THE FLEXIBILITY OF ADHESIVE IS DETERMINED BY THE AMOUNT OF CATALYST USED.
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TYPICAL PROPERTIES (SEMI-RIGID FORMULATION)

PROPERTIES	VALUE
TEMPERATURE RANGE	-70°F TO 250°F
HARDNESS, SHORE A	70
COLOR	BLACK
BOND STRENGTH IN SHEAR AT ROOM TEMPERATURE, PSI	3100
FLEXURAL STRENGTH, PSI	5500
IZOD IMPACT, FT LB/IN OF NOTCH	4.0
DIELECTIC STRENGTH, VOLTS/MIL	400
DISSIPATION FACTOR, 10^2 TO 10^9 Hz	.03 TO .04
MIXTURE: ECCOBOND AND CATALYST	1 TO 1 BY WEIGHT
POT LIFE	3 HOURS MIN AT ROOM TEMPERATURE
CURE TIME-ROOM TEMPERATURE	24 HOURS MINIMUM
160°F	30 MINUTES MINIMUM
220°F	15 MINUTES MINIMUM

APPROVED SOURCE(S) OF SUPPLY

VENDOR	VENDOR'S ITEM IDENT NO.	APPLICATION
NATIONAL STARCH AND CHEMICAL CO. EMERSON AND CUMING SPECIALTY POLYMERS DIV 869 WASHINGTON ST CANTON, MA 02021-2513 PHONE 781-828-3300 CAGE CODE 04552	ECCOBOND 45 CATALYST 15	EPOXY ADHESIVE USED ON ROCKET MOTORS AND ROCKET CATAPULTS

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D	30003	944AS110

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Figure 5. Typical Adhesive Used to Seal USRM Motor Tubes

1. PLATE IN ACCORDANCE WITH TABLE III.

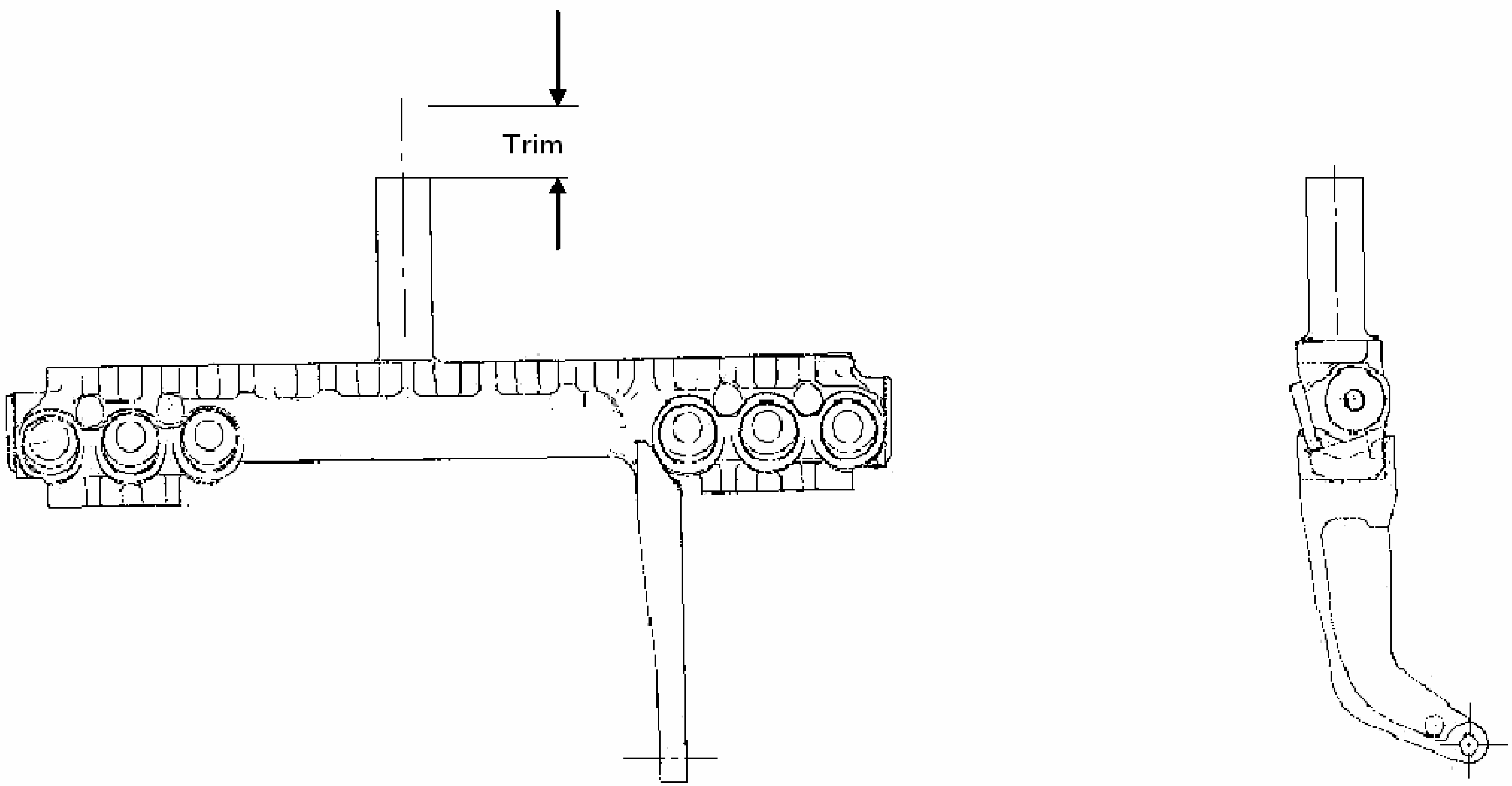


Figure 6. PAD MK 74 Manifold Torque Test Item

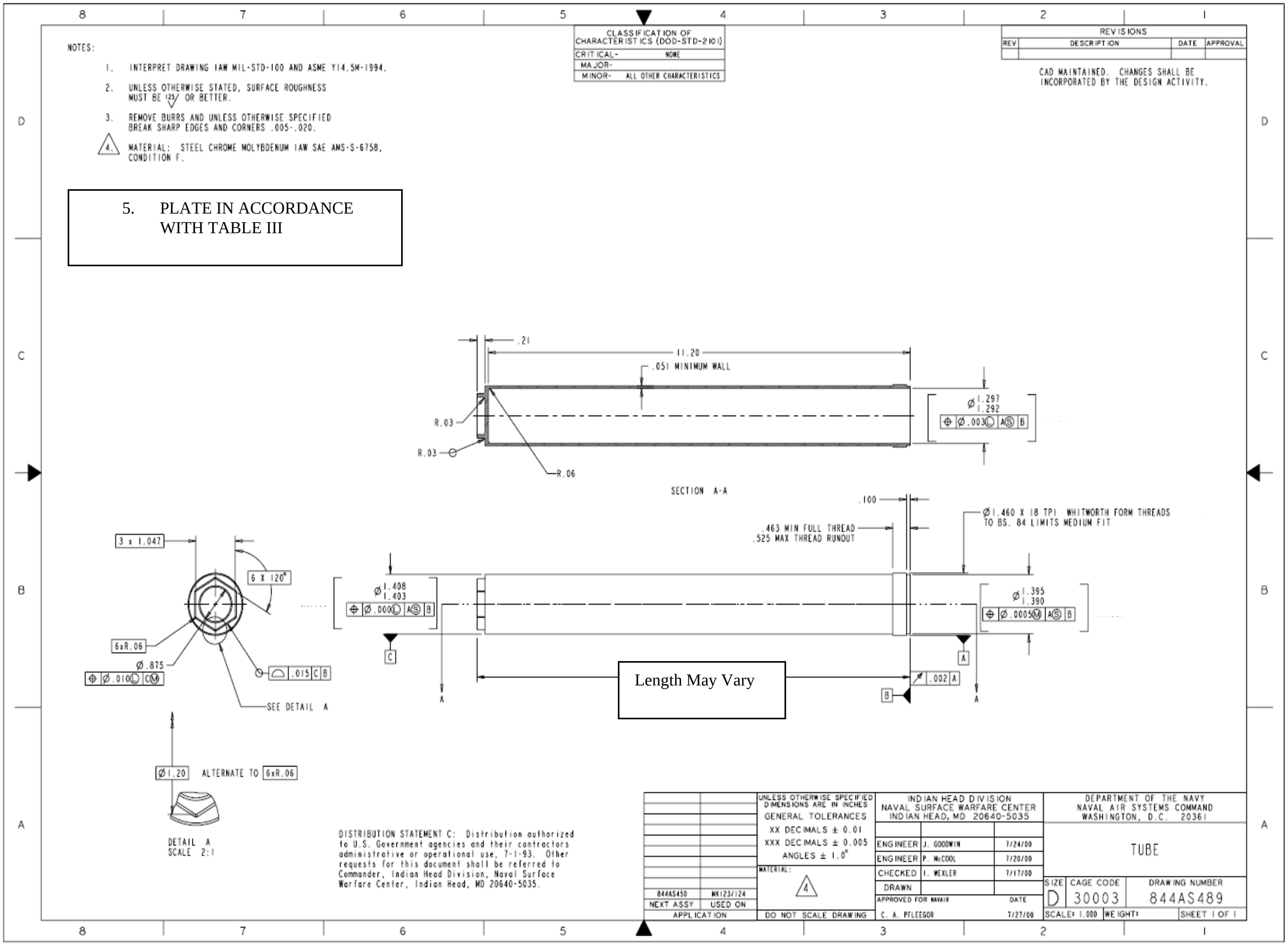


Figure 7. PAD MK 74 Manifold Tube Torque Test Item

Table III. Plating Preparation for PADs and CADs

Item designation	Quantity	Preparation description
Control	1 Mk 74 per Figure 4.	1. Strip and cadmium plated as per MIL-STD-870[24], Type II, Class 1, with plating .0005 in (0.013 mm) to .0007 (0.018 mm) thick on all surfaces. 2. Heat treat, to embrittlement relieve, as soon as possible after plating, but no later than 4 hours after plating at 374°F to 446°F (190°C to 230°C) for at least 24 hours.
	3 Motor tubes per Figure 5.	
	3 MC 50 (see Figure 6)	
(12) Trivalent coating Low-nickel	1 Mk 74 per Figure 4.	Strip and plate panel in accordance with drawing 513-174-0213 (Figure 6).
	3 Motor Tubes per Figure 5	
	3 MC 50 (see Figure 6)	
(12x) Trivalent coating High-nickel	1 Mk 74 per Figure 4. 3 Motor tubes per Figure 5.	Strip and plate panel in accordance with drawing SK07005-E213K-1 (Figure 7).

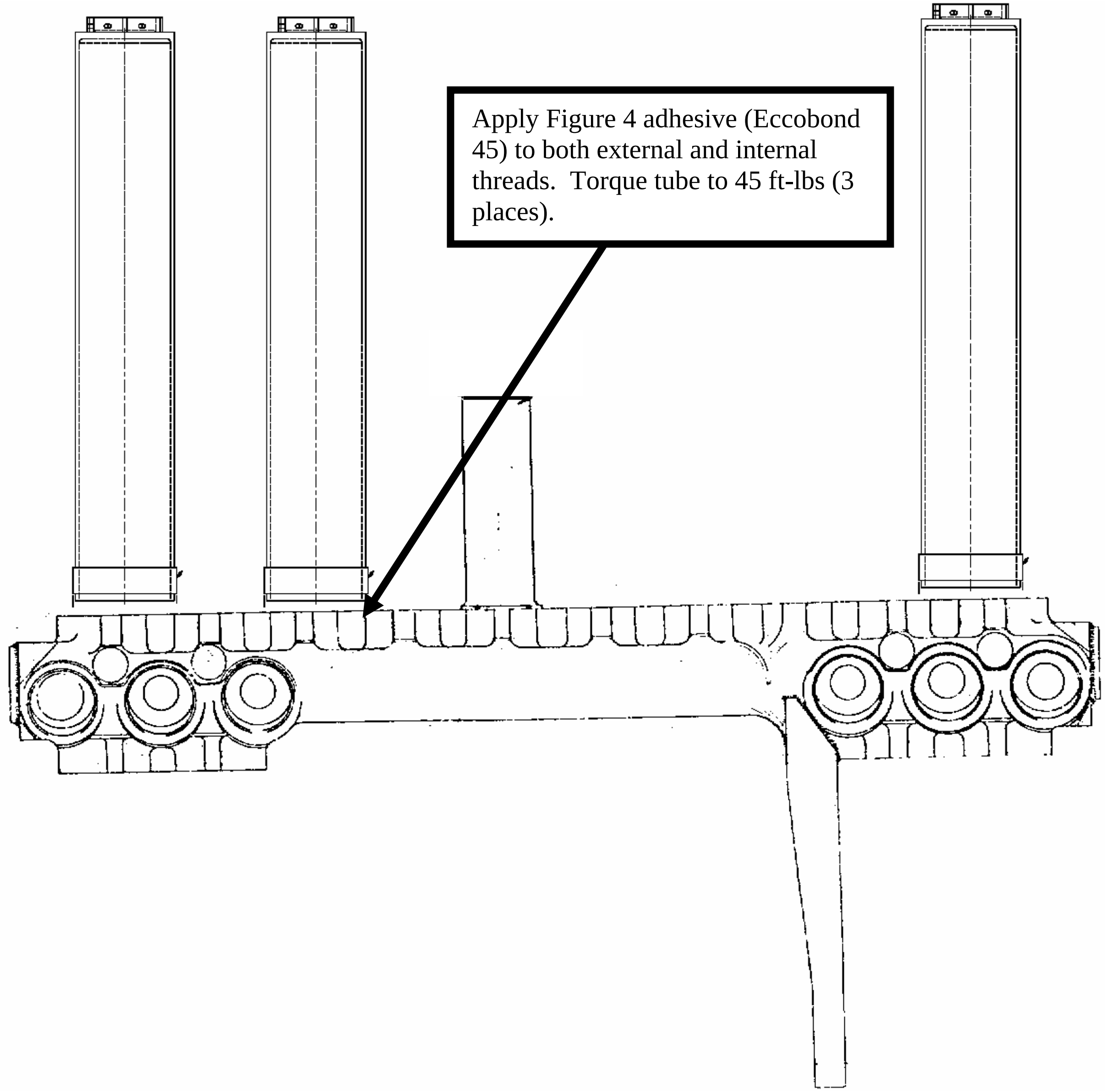


Figure 8. Modified MK 74 to Motor Tube Test Assembly

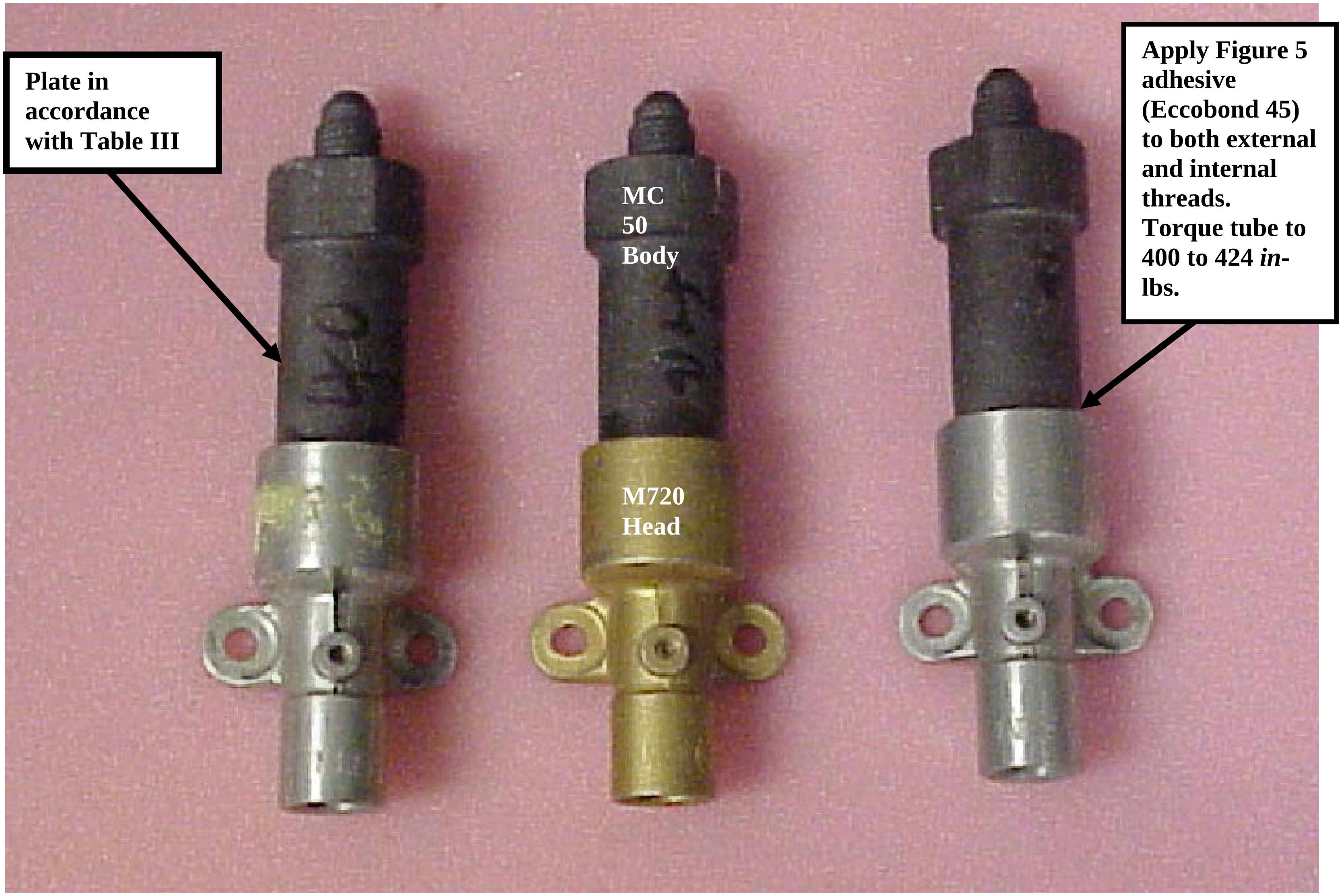
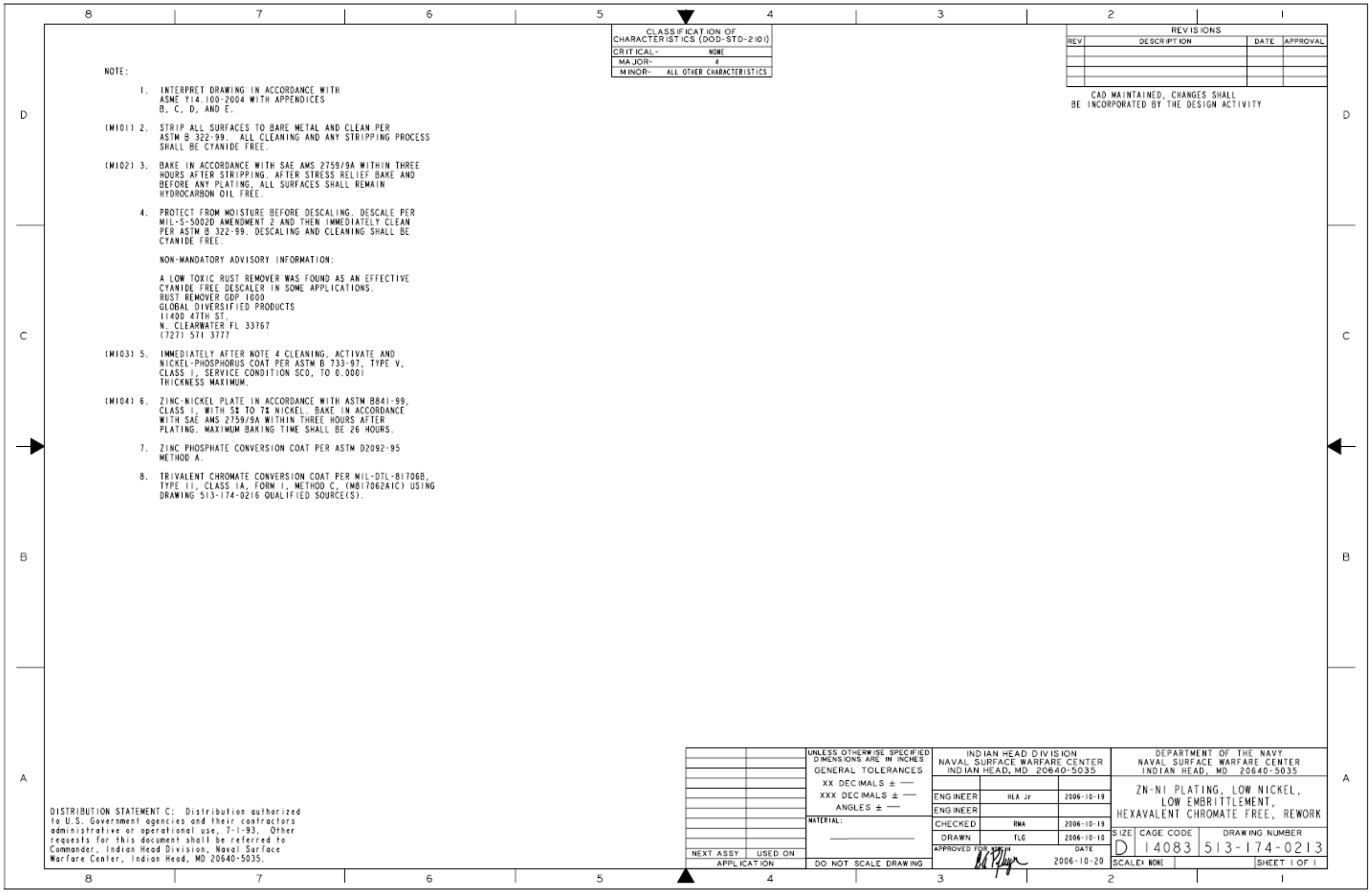


Figure 9. CAD Torque Test Assembly



CLASSIFICATION OF CHARACTERISTICS (DOD-STD-2101)	
CRITICAL-	NONE
MAJOR-	4
MINOR-	ALL OTHER CHARACTERISTICS

REVISIONS			
REV	DESCRIPTION	DATE	APPROVAL

CAD MAINTAINED, CHANGES SHALL BE INCORPORATED BY THE DESIGN ACTIVITY

NOTE:

1. INTERPRET DRAWING IN ACCORDANCE WITH ASME Y14.100-2004 WITH APPENDICES B, C, D, AND E.

(M101) 2. STRIP ALL SURFACES TO BARE METAL AND CLEAN PER ASTM B 322-99. ALL CLEANING AND ANY STRIPPING PROCESS SHALL BE CYANIDE FREE.

(M102) 3. BAKE IN ACCORDANCE WITH SAE AMS 2759/9A WITHIN THREE HOURS AFTER STRIPPING. AFTER STRESS RELIEF BAKE AND BEFORE ANY PLATING, ALL SURFACES SHALL REMAIN HYDROCARBON OIL FREE.

4. PROTECT FROM MOISTURE BEFORE DESCALING. DESCALE PER MIL-S-5002D AMENDMENT 2 AND THEN IMMEDIATELY CLEAN PER ASTM B 322-99. DESCALING AND CLEANING SHALL BE CYANIDE FREE.

NON-MANDATORY ADVISORY INFORMATION:

A LOW TOXIC RUST REMOVER WAS FOUND AS AN EFFECTIVE CYANIDE FREE DESCALER IN SOME APPLICATIONS.
RUST REMOVER GDP 1000
GLOBAL DIVERSIFIED PRODUCTS
11400 47TH ST.
N. CLEARWATER FL 33767
(727) 571 3777

(M103) 5. IMMEDIATELY AFTER NOTE 4 CLEANING, ACTIVATE AND NICKEL-PHOSPHORUS COAT PER ASTM B 733-97, TYPE V, CLASS 1, SERVICE CONDITION SC0, TO 0.0001 THICKNESS MAXIMUM.

(M104) 6. ZINC-NICKEL PLATE IN ACCORDANCE WITH ASTM B841-99, CLASS 1, WITH 5% TO 7% NICKEL. BAKE IN ACCORDANCE WITH SAE AMS 2759/9A WITHIN THREE HOURS AFTER PLATING. MAXIMUM BAKING TIME SHALL BE 26 HOURS.

7. ZINC PHOSPHATE CONVERSION COAT PER ASTM D2092-95 METHOD A.

8. TRIVALENT CHROMATE CONVERSION COAT PER MIL-DTL-81706B, TYPE II, CLASS 1A, FORM 1, METHOD C, (M81706 2A1C) USING DRAWING 513-174-0216 QUALIFIED SOURCE(S).

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NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
GENERAL TOLERANCES
XX DECIMALS ± —
XXX DECIMALS ± —
ANGLES ± —
MATERIAL:
DO NOT SCALE DRAWING

INDIAN HEAD DIVISION
NAVAL SURFACE WARFARE CENTER
INDIAN HEAD, MD 20640-5035

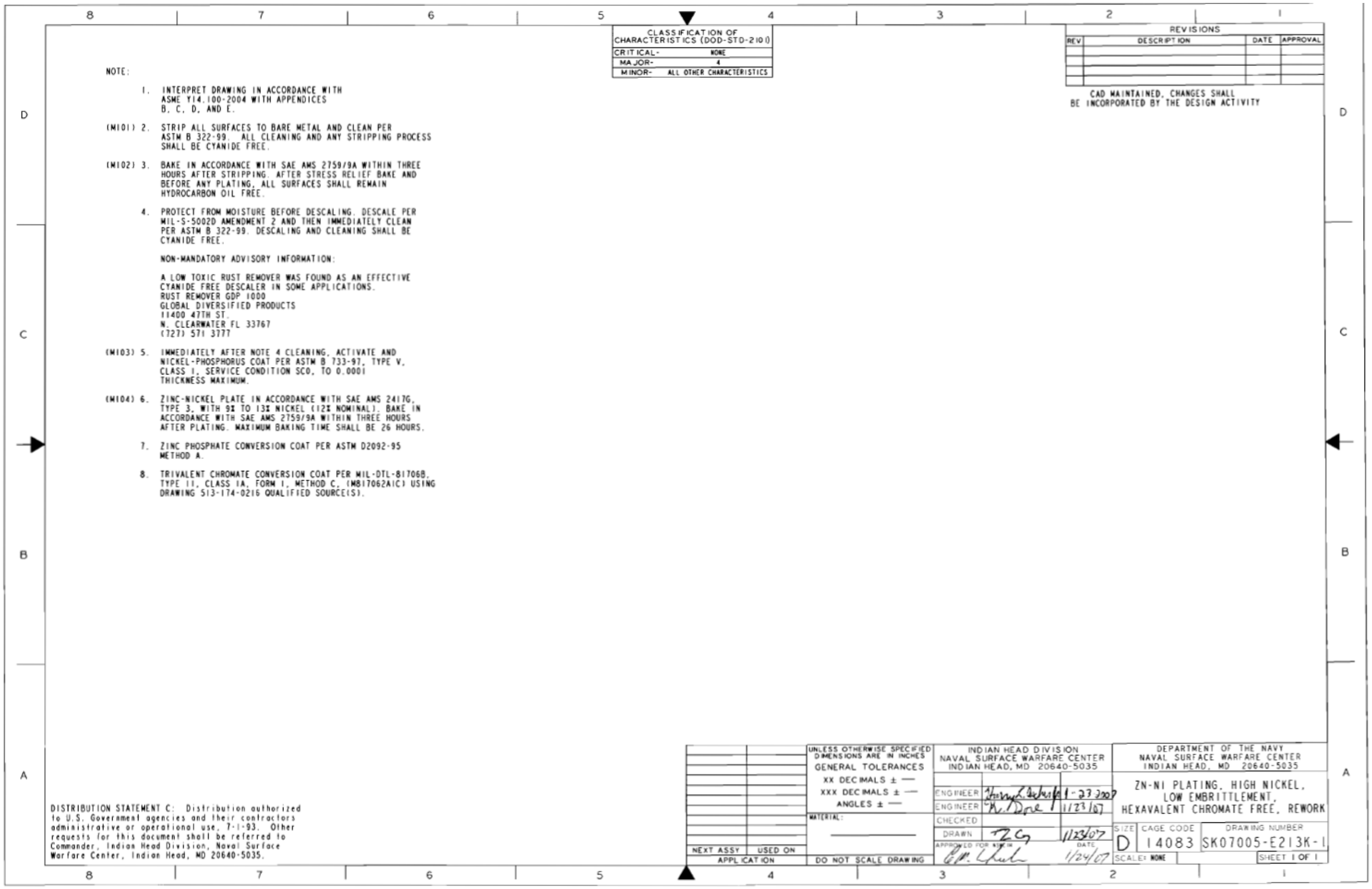
ENGINEER	HLA Jr	2006-10-19
ENGINEER		
CHECKED	RMA	2006-10-19
DRAWN	TLG	2006-10-10
APPROVED FOR		DATE 2006-10-20

DEPARTMENT OF THE NAVY
NAVAL SURFACE WARFARE CENTER
INDIAN HEAD, MD 20640-5035

ZN-NI PLATING, LOW NICKEL, LOW EMBRITTLEMENT, HEXAVALENT CHROMATE FREE, REWORK

SIZE	CAGE CODE	DRAWING NUMBER
D	14083	513-174-0213
SCALE: NONE		SHEET 1 OF 1

Figure 10. Zinc-Nickel Plating, Low-Nickel, Low Embrittlement, Hexavalent-Chromate Free Rework (ID 12)[5,11,8,9,10,12,13]



CLASSIFICATION OF CHARACTERISTICS (DOD-STD-2101)

CRITICAL-	NONE
MAJOR-	4
MINOR-	ALL OTHER CHARACTERISTICS

REVISIONS

REV	DESCRIPTION	DATE	APPROVAL

CAD MAINTAINED, CHANGES SHALL BE INCORPORATED BY THE DESIGN ACTIVITY

NOTE:

1. INTERPRET DRAWING IN ACCORDANCE WITH ASME Y14.100-2004 WITH APPENDICES B, C, D, AND E.

(M101) 2. STRIP ALL SURFACES TO BARE METAL AND CLEAN PER ASTM B 322-99. ALL CLEANING AND ANY STRIPPING PROCESS SHALL BE CYANIDE FREE.

(M102) 3. BAKE IN ACCORDANCE WITH SAE AMS 2759/9A WITHIN THREE HOURS AFTER STRIPPING. AFTER STRESS RELIEF BAKE AND BEFORE ANY PLATING, ALL SURFACES SHALL REMAIN HYDROCARBON OIL FREE.

4. PROTECT FROM MOISTURE BEFORE DESCALING. DESCALE PER MIL-S-5002D AMENDMENT 2 AND THEN IMMEDIATELY CLEAN PER ASTM B 322-99. DESCALING AND CLEANING SHALL BE CYANIDE FREE.

NON-MANDATORY ADVISORY INFORMATION:

A LOW TOXIC RUST REMOVER WAS FOUND AS AN EFFECTIVE CYANIDE FREE DESCALER IN SOME APPLICATIONS.
RUST REMOVER GDP 1000
GLOBAL DIVERSIFIED PRODUCTS
11400 47TH ST.
N. CLEARWATER FL 33767
(727) 571 3777

(M103) 5. IMMEDIATELY AFTER NOTE 4 CLEANING, ACTIVATE AND NICKEL-PHOSPHORUS COAT PER ASTM B 733-97, TYPE V, CLASS 1, SERVICE CONDITION SC0, TO 0.0001 THICKNESS MAXIMUM.

(M104) 6. ZINC-NICKEL PLATE IN ACCORDANCE WITH SAE AMS 2417G, TYPE 3, WITH 9% TO 13% NICKEL (12% NOMINAL). BAKE IN ACCORDANCE WITH SAE AMS 2759/9A WITHIN THREE HOURS AFTER PLATING. MAXIMUM BAKING TIME SHALL BE 26 HOURS.

7. ZINC PHOSPHATE CONVERSION COAT PER ASTM D2092-95 METHOD A.

8. TRIVALENT CHROMATE CONVERSION COAT PER MIL-DTL-81706B, TYPE II, CLASS 1A, FORM 1, METHOD C, (M81706 2A1C) USING DRAWING 513-174-0216 QUALIFIED SOURCE(S).

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NEXT ASSY | USED ON
APPLICATION

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
GENERAL TOLERANCES
XX DECIMALS ± —
XXX DECIMALS ± —
ANGLES ± —
MATERIAL:
DO NOT SCALE DRAWING

INDIAN HEAD DIVISION
NAVAL SURFACE WARFARE CENTER
INDIAN HEAD, MD 20640-5035

ENGINEER	[signature]	1-23-2007
ENGINEER	K. Dore	1/23/07
CHECKED		
DRAWN	TZG	1/23/07
APPROVED FOR NSWC IH	[signature]	DATE 1/24/07

DEPARTMENT OF THE NAVY
NAVAL SURFACE WARFARE CENTER
INDIAN HEAD, MD 20640-5035

ZN-NI PLATING, HIGH NICKEL, LOW EMBRITTLEMENT, HEXAVALENT CHROMATE FREE, REWORK

SIZE	CAGE CODE	DRAWING NUMBER
D	14083	SK07005-E213K-1

SCALE: NONE | SHEET 1 OF 1

Figure 11. Zinc-Nickel Plating, High-Nickel, Low Embrittlement, Hexavalent-Chromate Free Rework (ID 12x)[5,11,8,9,14,12,13]

TEST RESULTS AND DISCUSSION

Environmental Testing

Test Panel Rain, Humidity, Cyclic Salt Fog

Figures 12 and 13 show results from the six TCP panels designated 12-1, 12-2, 12-3, 12x-1, 12x-2, and 12x-3 subject to rain, humidity and 1000 hours of cyclic salt-fog testing per Table II, displayed no apparent damage from chalking or rusting. Figure 14 shows 2000 and 3000 hours cyclic salt fog testing. Although these panels were not evaluated for blistering, checking, cracking, flaking, or filiform corrosion, these panels displayed no apparent damage of any type. By comparison, the untreated control panels exhibited increasing levels of rust. It became totally covered by thick corrosion by the 1000-hour salt-fog evaluation. After 3000 hours, the control lost 36% of its original weight to rust. White residue observed on the panels during salt-fog testing are artifacts of salt deposits related to the test environment and not damage to sample's surface. Whiter residue appears on the low-nickel panels more than the high-nickel panels.

These results are superior to cadmium with CCC or zinc high-nickel with CCC shown in IHTR 2694, Table XI[3].

Test Panel Sulfur Dioxide and Cyclic Salt Fog Unpainted

Figure 15 shows the progress of corrosion during sulfur dioxide/salt fog testing. Figure 16 shows that the higher nickel content fairs somewhat better at 4 days than the low nickel content. Figure 15 and 17 show that all panels exhibited substantial red rust in one week.

Test Panel Sulfur Dioxide and Cyclic Salt Fog Painted

Figure 18 illustrates a comparison between painted cadmium plated panels and painted TCP on low zinc nickel. These painted CCC on cadmium plated panel resist blistering and score corrosion the best. Painted TCP on low zinc nickel that was previously rain/humidity/salt fog tested exhibited only moderate blistering and score corrosion throughout the 78 day testing.

Figure 19 illustrates how effective TCP is in reducing corrosion in sulfur dioxide testing. The second panel from the left has substantially more corrosion than the two TCP panels on the right. Also note that the cadmium panel has no blistering whereas the three panels on the right have blisters.

Test Panel Chip Resistance

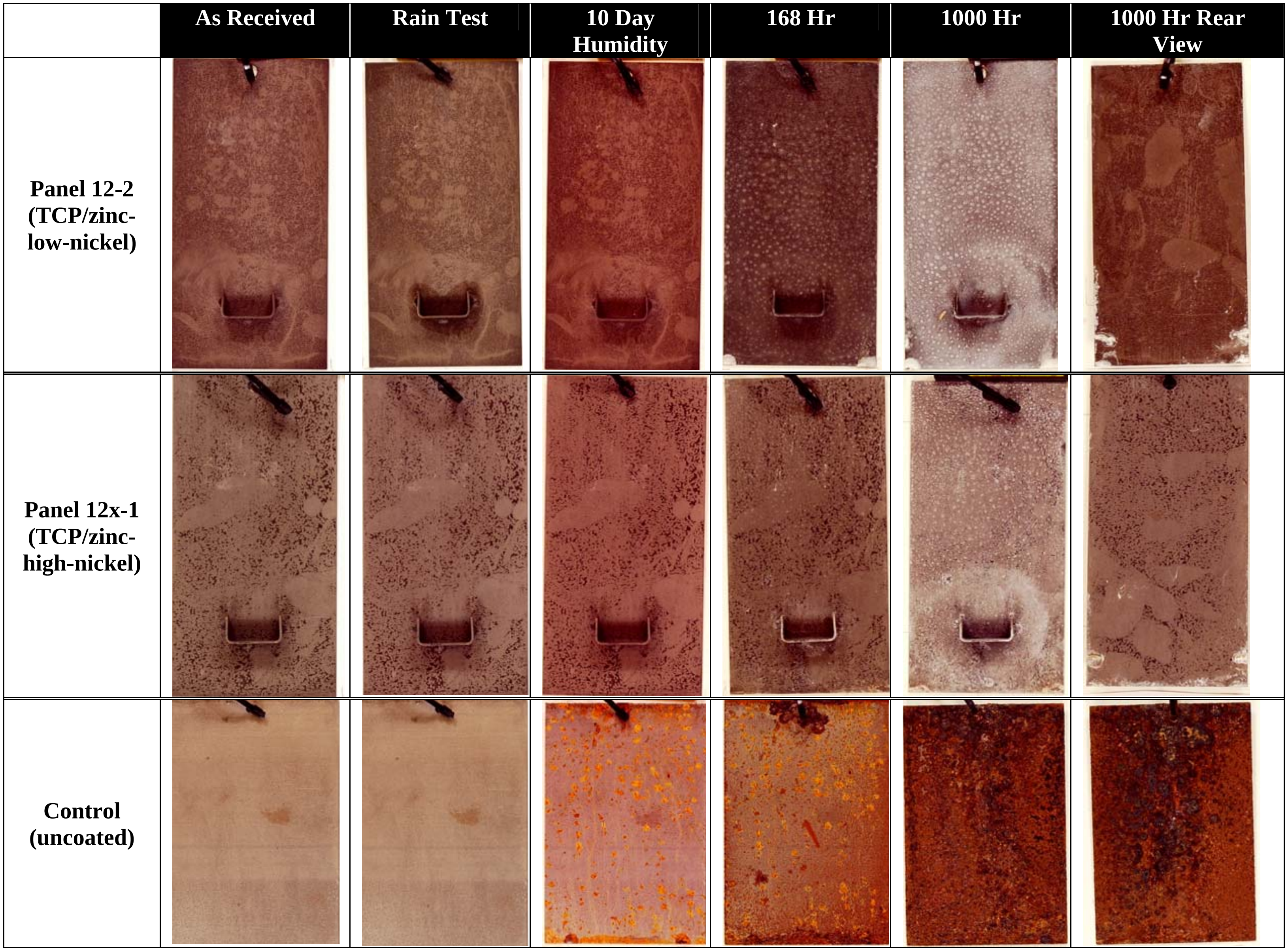
Table IV shows evaluations on the five TCP panels (three as the control with TCP over zinc-nickel (5 percent), and two with TCP over zinc-nickel (12 percent) subjected to chip resistance testing, indicated minimal and acceptable damage to panels with both TCP treatments.) Both groups of panels displayed similar chipping resistance ratings for both treatments. Therefore, the 12 percent nickel TCP receives a “pass” for this test.

Torque Retention

Table V shows results from the tube breakaway torque tests. All the assemblies required more torque to unscrew than the torque used to assemble them.

Compatibility

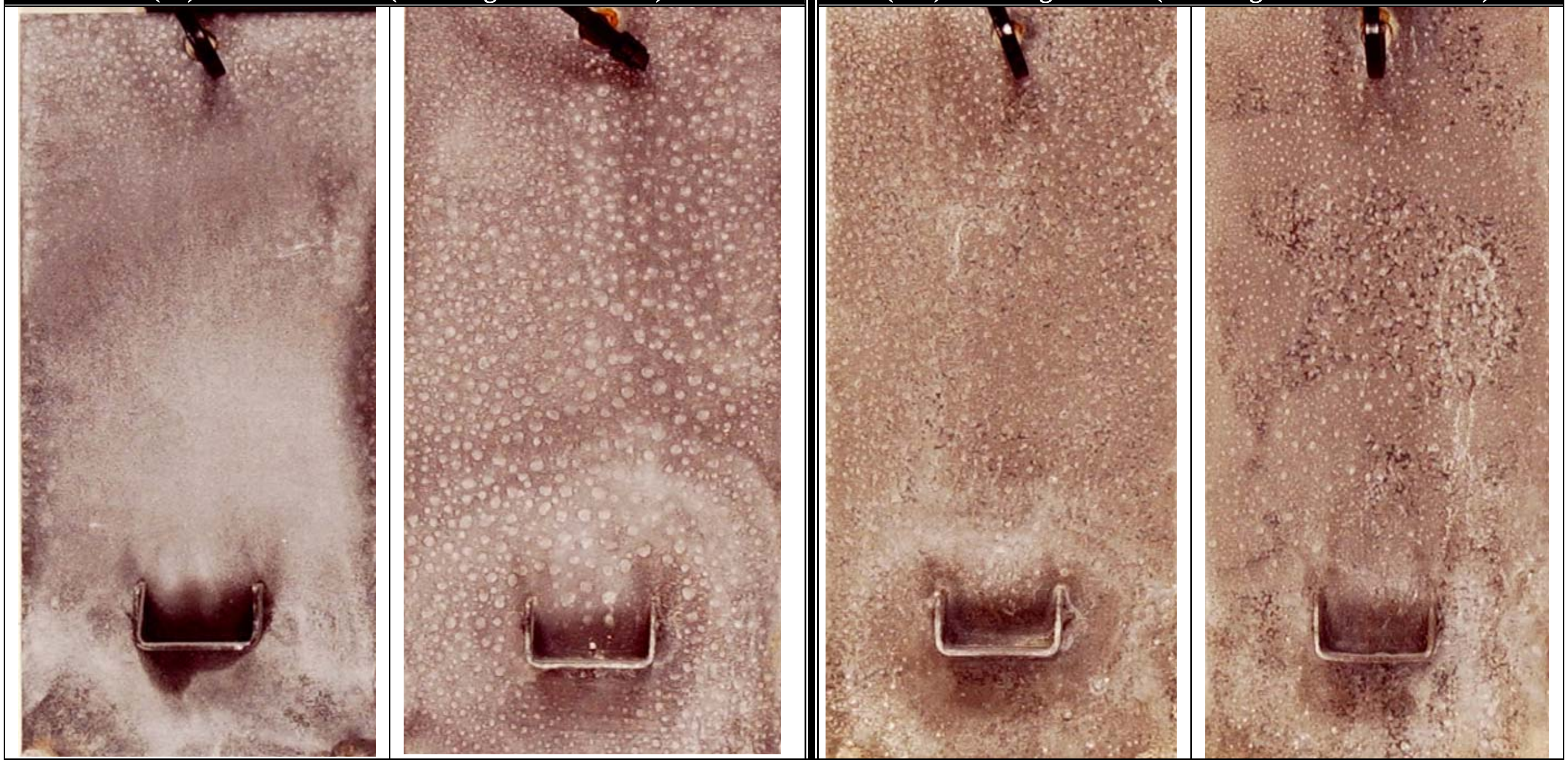
Appendix A contains a series of differential scanning calorimetry (DSC), and Thermogravimetric Analysis compatibility test. They revealed that TCP is compatible with Mechanite 19. Mechanite 19 is a double-base (nitrocellulose/nitroglycerine) propellant used in some CAD/PAD items.



Note: All ASTM G85 salt fog tests were performed in Auto-Technology Model CCT-NC-20.

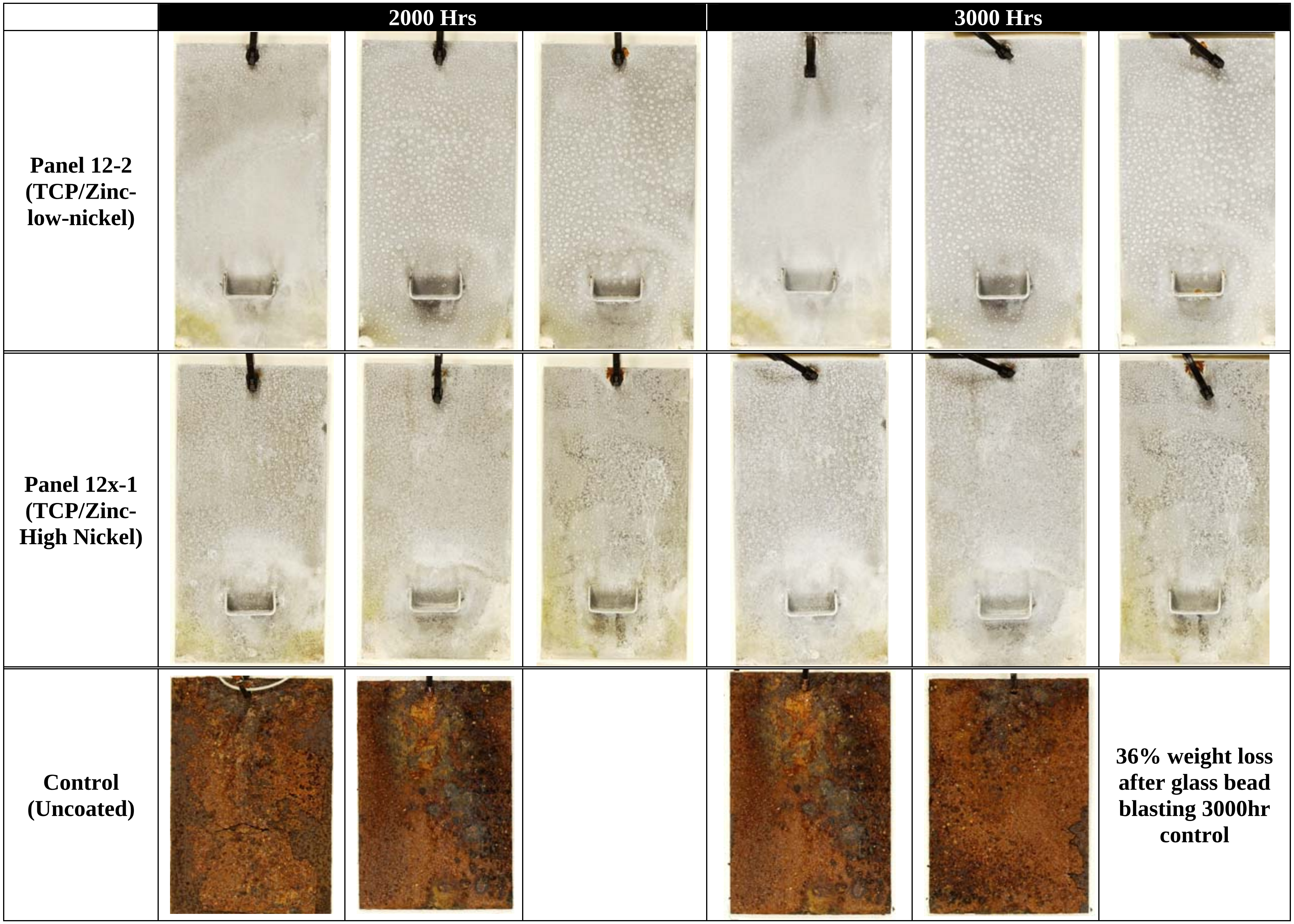
Figure 12. Photos of TCP/Zinc-Nickel/Steel Panels After Various Stages of Salt Fog Testing

(12) Zinc-low-nickel (Drawing 513-174-0215)	(12x) Zinc-high Nickel (Drawing SK07005-E213K-2)



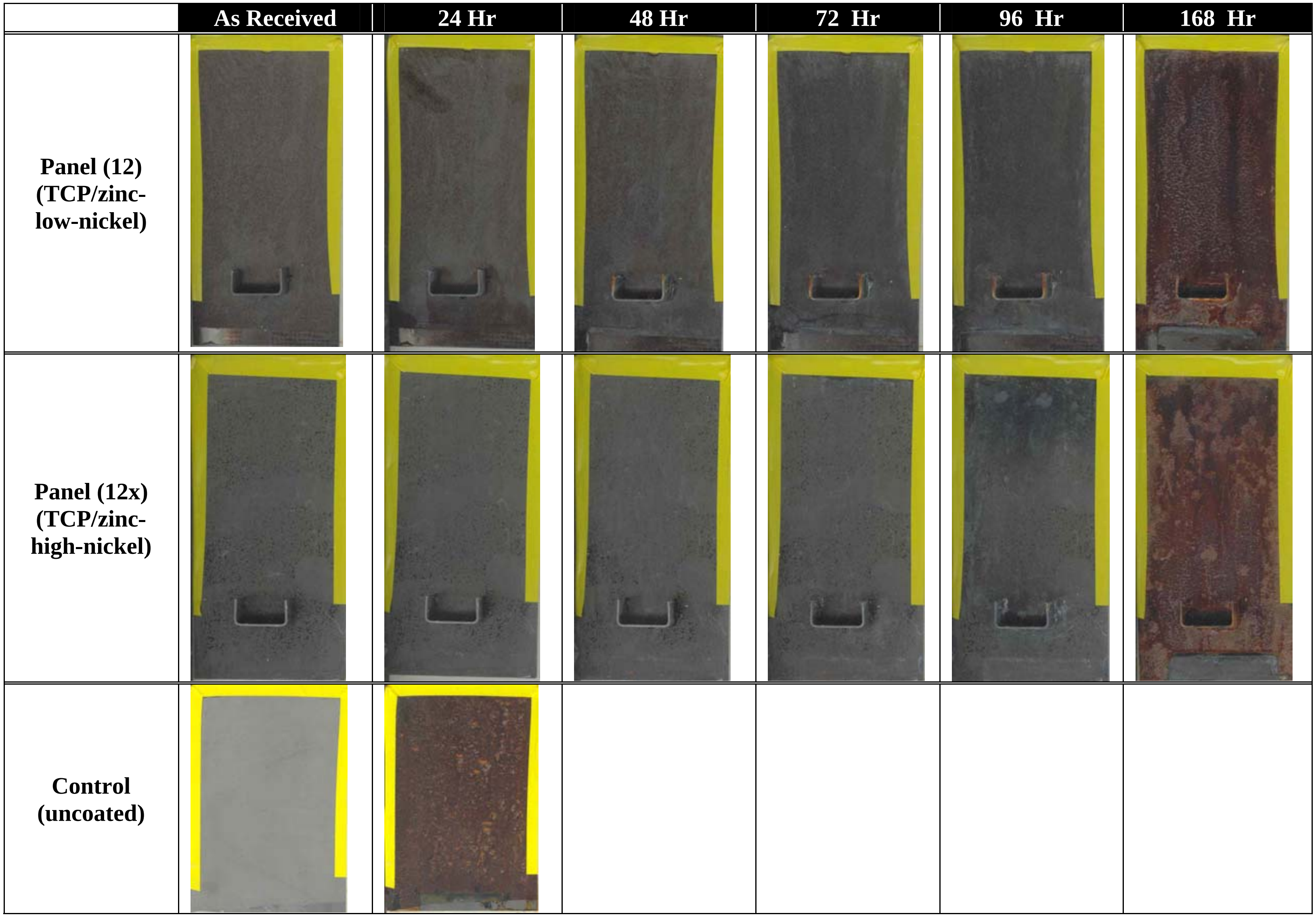
Note: All ASTM G85 salt fog tests were performed in Auto-Technology Model CCT-NC-20.

Figure 13. 1000 Hr Cyclic Salt Fog Test of TCP/Zinc-Nickel/Steel Panels



Note: All sulfur dioxide salt fog tests were performed in a Harshaw Environmental Test Chamber of Engehard Corporation, Cleveland, OH.

Figure 14. 2000 and 3000 Hr Cyclic Salt Fog Test of TCP/Zinc-Nickel/Steel Panels



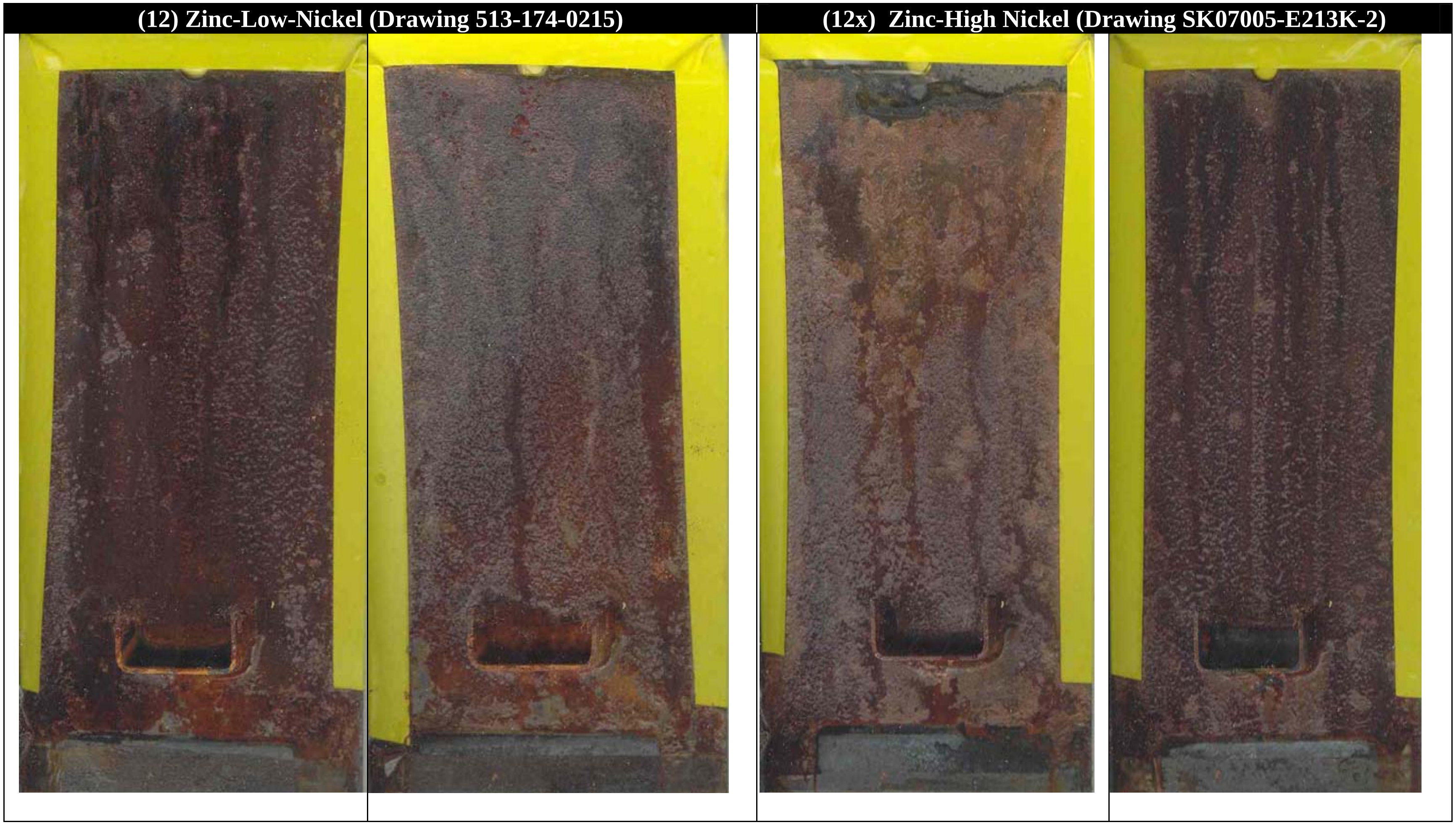
Note: All sulfur dioxide salt fog tests were performed in a Harshaw Environmental Test Chamber of Engehard Corporation, Cleveland, OH.

Figure 15. Sulfur Dioxide/Salt Fog Testing on TCP/Zinc-Nickel/Steel Panels After Various Stages

(12) Zinc-Low-Nickel (Drawing 513-174-0215)	(12x) Zinc-High Nickel (Drawing SK07005-E213K-2)

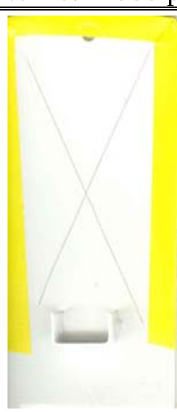
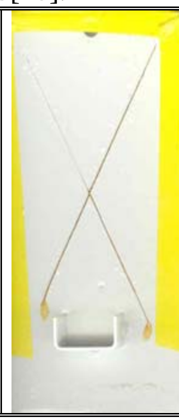
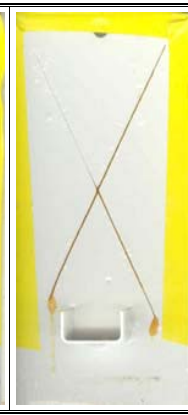
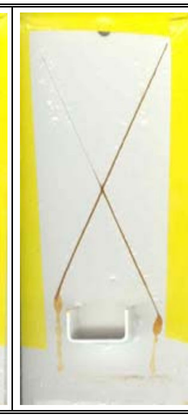
Note: All sulfur dioxide salt fog tests were performed in a Harshaw Environmental Test Chamber of Engehard Corporation, Cleveland, OH.

Figure 16. 92 Hr (4 days) Sulfur Dioxide/Salt Fog Testing on TCP/Zinc Nickel



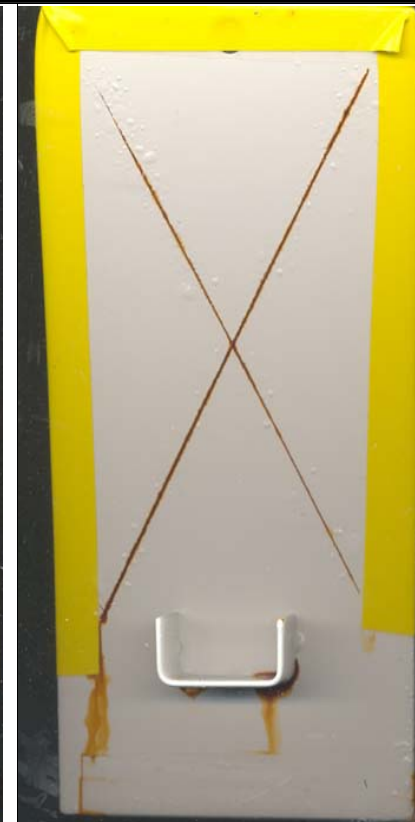
Note: All sulfur dioxide salt fog tests were performed in a Harshaw Environmental Test Chamber of Engehard Corporation, Cleveland, OH.

Figure 17. 168 Hr (1 Week) Sulfur Dioxide/Salt Fog Testing on TCP/Zinc Nickel

<table>
<tr><th></th><th>As Received</th><th>168 Hr</th><th>336 Hr</th><th>504 Hr</th><th>672 Hr</th><th>840 Hr</th><th>1008 Hr</th><th>1872 Hr</th></tr>
<tr><td>Painted Cadmium (Control)</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="9">Cadmium plate as per MIL-STD-870[24], Type II, Class 1, with plating .0005 (0.013 mm) to .0007 (0.018 mm) thick on all surfaces. Then heat treat, to embrittlement relieve, as soon as possible after plating, but no later than 4 hr after plating at 374 °F to 446 °F (190 °C to 230 °C) for at least 24 hr. Prime and Paint as per MIL-DTL-85097[15]. Primer coating shall be per MIL-P-53030[16]. Paint shall be as per MIL-PRF-85285[17], Color, Gloss White No. 17935 per FED-STD-595[18].</td></tr>
<tr><td>Previously subject to rain test, 10 days humidity and 120 days salt fog then freshly scored before Sulfur dioxide/salt fog testing (used 6p23 in IHTR 2694 Table VIII)</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="9">Plated per drawing 513-174-0215. Prime and Painted per MIL-DTL-85097[15]. Primer coating per MIL-P-53030[16]. Paint per MIL-PRF-85285[17], Color, Gloss White No. 17935 per FED-STD-595[18].</td></tr>
</table>

Note: All sulfur dioxide salt fog tests were performed in a Harshaw Environmental Test Chamber of Engehard Corporation, Cleveland, OH.

Figure 18. Painted After Various Stages Of Sulfur Dioxide/Salt Fog Testing Per Table II

Cadmium Plated per Table III (Control)	No TCP (Step 8) on Zinc-Low-Nickel (Drawing 513-174-0215)	TCP on Zinc-Low-Nickel (Drawing 513-174-0215)	
			
Prime and painted per MIL-DTL-85097[15]. Primer coating per MIL-P-53030[16]. Paint per MIL-PRF-85285[17], Color, Gloss White No. 17935 per FED-STD-595[18].			

Note: All sulfur dioxide salt fog tests were performed in a Harshaw Environmental Test Chamber of Engehard Corporation, Cleveland, OH.

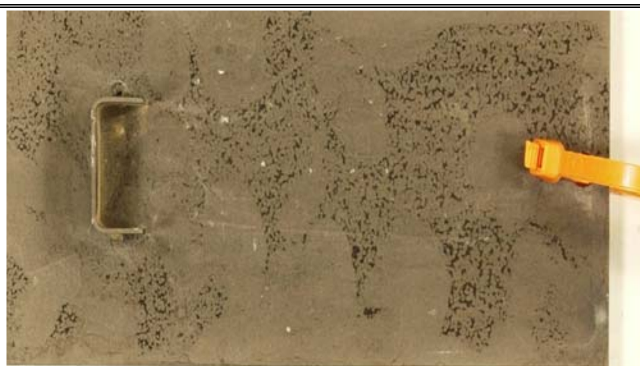
Figure 19. Photos of Painted after 1872 Hrs (78 days) Sulfur Dioxide/Salt Fog Testing

Table IV. Chip Resistance Test TCP/Zinc-Nickel Results

<table>
<tr><th>Designation</th><th>Typical panels

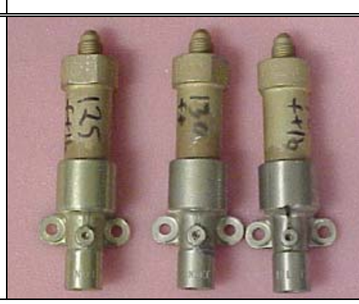
Coating (treatment) chipping resistance test procedure:
ASTM D3170-03[22]

Testing performed by: Graig Jolley, NSWCCD Code 614
Test date: 17 August 2007

Panels evaluation performed by: Dan Davis, NSWCCD Code 613</th><th>Panel ID Chip No. Rating[1]</th><th>Chip Size Rating[1]</th><th>Pass/Fail</th></tr>
<tr><td>12-4</td><td rowspan="3"></td><td>7</td><td>A</td><td>Pass</td></tr>
<tr><td>12-5</td><td>6</td><td>A</td><td>Pass</td></tr>
<tr><td>12-6</td><td>6</td><td>A</td><td>Pass</td></tr>
<tr><td colspan="5">(Plated per drawing 513-174-0215 (Figure 1))</td></tr>
<tr><td>12x-4</td><td rowspan="2"></td><td>6</td><td>A</td><td>Pass</td></tr>
<tr><td>12x-5</td><td>6</td><td>A</td><td>Pass</td></tr>
<tr><td colspan="5">(Plated per drawing SK07005-E213K-1 (Figure 2))</td></tr>
</table>

[1]Chip number and size ratings evaluated per ASTM D3170-03[23] and SAE J400[25] (Nov. 2002 Rev), using the “physical count method” (number of chips of each size).

Table V. Unscrew Torque Typical PADs and CADs Test Results[1]

Designation	PADs: Underseat rocket motor manifold/tubes (See Figure 8)	Unscrew torque ft-lb	As a percent of 45 ft-lb applied torque[2]
(12) Zinc-low nickel plated per 513-174-0213 (Figure 10)		90	200%
		120	270%
		120	270%
		Avg: 110 σ 17	240%
(12x) Zinc-high nickel plated per SK07005-E213K-1 (figure 11)		95	210%
		85	190%
		100	220%
		Avg: 93 σ 8	210%
Figure 8; Cadmium plate per table III (control)		80	180%
		110	240%
		125	280%
		Avg: 105 σ 23	230%
Designation	CADs: MC 50 Steel Body (See Figure 9)	Unscrew torque in-lb	As a percent of Avg. 400-425 in-lb Applied Torque[2]
(12) Zinc-low nickel plated per 513-174-0213 (Figure 10)		960	230%
		480	120%
		900	220%
		Avg: 780 σ 260	190%
(Control) cadmium plate per table III		1500	360%
		840	200%
		1560	380%
		Avg: 1300 σ 400	320%

[1] All assemblies cured one week at room temperature after assembly.
[2] Torque wrench serial number is 11389. Calibration due 06-16-2007.

CONCLUSION

- Zinc-Nickel plate on 4130 steel prepared in accordance with 513-174-0215 or 513-174-0213 is qualified for CAD/PAD service provided it is compatible with the materials it may be in contact in the CAD/PAD.

- TCP/zinc-phosphate conversion coating offers a low toxicity alternative to hexavalent chromate on zinc-nickel plated 4130 steel. The TCP without zinc-phosphate on zinc-nickel plated steel is unlikely to provide corrosion protection due to the porous nature of zinc-nickel and the aqueous nature of TCP corroding from within these pores. This is based on testing by the TCP's co-inventor and previous testing using aqueous Teflon® to replace hexavalent chromate (See IHTR 2694, Table XII)[3].

- TCP is compatible with Mechanite 19 propellant.

- TCP/zinc-phosphate/zinc-low-nickel is qualified for all PADs and CADs assuming it is compatible with the various materials (i.e., propellants) used in the same.

- TCP/zinc-phosphate/zinc-high nickel has somewhat better corrosion resistance in sulfur dioxide/salt fog environments than TCP/zinc-phosphate/zinc-low-nickel.

- TCP/zinc-phosphate/zinc-low-nickel offers much better corrosion protection than CCC/cadmium or CCC/zinc-low-nickel.

- TCP/zinc-phosphate/zinc-nickel is non-proprietary.

- TCP/zinc-phosphate/zinc-low/high nickel plating on thread wetted with Eccobond 45 adhesive is unlikely to lose preload torque after cure.

- TCP/zinc-phosphate/zinc-low or high-nickel plated CAD can endure shipboard marine application provided exposure to sulfur dioxide is not too extreme.

- TCP/zinc-phosphate/zinc-low or high-nickel plated CAD can endure long term exterior marine applications even unpainted (painted TCP/zinc-phosphate/zinc-high nickel was *never* tested).

- TCP/Zn-P/Zn-Ni used as prescribed in Figures 1, 2, 10, and 11 exceeds all of our objectives.

- TCP/Zn-P/Zn-Ni used as prescribed in Figures 1, 2, 10, and 11 is qualified to replace CCC/Cd on steel CADs and PADs, provided it is compatible with materials it would be exposed to in the CAD or PAD (e.g., propellant, energetics, dissimilar material etc.).

RECOMMENDATIONS

- If the trivalent chromate described in this report is compatible with materials it would be exposed to in a CAD or PAD, replace the hexavalent chromate/cadmium plating on steel PAD or CAD surfaces with trivalent chromate/zinc phosphate/zinc nickel/nickel strike in accordance with drawing number:

    - 513-174-0215 (Figure 1) on new parts
    - 513-174-0213 (Figure 10) on reworked parts
    - SK07005-E213K-2 (Figure 2) on new parts subject to severe SO_2 fog on unpainted surfaces
    - SK07005-E213K-1 (Figure 11) on reworked parts subject to severe SO_2 fog on unpainted surfaces.

- This plating is thicker than cadmium plating. Therefore, if final part dimensions apply after plating, assure that this coating system does not violate any minimum wall or size requirements before any final production.

- Replace cadmium plating on steel in all CAD/PAD rework specifications as recommended in the first and second bullets.

- Replace cadmium plating on steel in all production CAD/PAD technical data packages as recommended in the first and second bullets.

REFERENCES

1. US Department of Labor Occupational Safety and Health Administration, Hexavalent Chromium Standards, Section 5(a)(1) and 5(a)(2) of the OSHA Act, February 28, 2006.

2. Federal Register / Vol. 71, No. 209 / Monday, October 30, 2006, Rules and Regulations, Page 63238, 29 CFR 1910.

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4. *Protective Coating Analysis*, Sabal, Diane L. and Dohm, Gregory J., SAFE Journal 35, p209-p217, 1997.

5. ASME Y14.100-2000, *Engineering Drawing Practices*, November 23, 2001.

6. ASTM B 322, *Standard Guide for Cleaning Metals Prior to Electroplating*, November 10, 1999.

7. ASTM B 849-94, *Standard Specification for Pre-Treatments of Iron or Steel for Reducing Risk of Hydrogen Embrittlement*, July 15, 1994.

8. MIL-S-5002, *Surface Treatments and Inorganic Coatings for Metal Surfaces of Weapons Systems*, October 20, 1999.

9. ASTM B 733 - 97 *Standard Specification for Autocatalytic (Electroless) Nickel-Phosphorus Coatings on Metal*, July 10, 1997.

10. ASTM B 849-99, *Standard Specification for Pre-Treatments of Iron or Steel for Reducing Risk of Hydrogen Embrittlement*, November 10, 1999.

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12. ASTM D 2092, *Standard Guide for Preparation of Zinc-Coated (Galvanized) Steel Surfaces for Painting*, April 15, 1995.

13. MIL-DTL-81706B, *Chemical Conversion Materials for Coating Aluminum and Aluminum Alloy*s, October 25, 2004.

14. SAE AMS 2417G, *Plating, Zinc-Nickel Alloy*, July 2004.

15. MIL-DTL-85097, *USN/USMC Propellant Actuated Devices (PADS), General Specification for*, July 7, 2000.

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17. MIL-PRF-85285, *Coating: Polyurethane, Aircraft and Support Equipment*, April 30, 1997.

18. FED-STD-595, *Colors Used in Government Procurement*, December 15, 1989.

19. ASTM D 2247-99, *Standard Practice for Testing Water Resistance of Coatings in 100% Relative Humidity*, December 10, 1999.

20. MIL-P-83126A, *Propulsion Systems, Aircrew Escape, Design Specification for*, February 8, 1980.

21. ASTM G 85, *Standard Practice for Modified Salt Spray (Fog) Testing*, October 10, 2002.

22. ASTM D 3170, *Standard Test Method for Chipping Resistance of Coatings*, July 10, 2003.

23. SAE AMS-S-6758, *Steel, Chrome-Molybdenum (4130) Bars and Reforging Stock (Aircraft Quality)*, July 1, 1998.

24. MIL-STD-870, *Cadmium Plating, Low Embrittlement, Electrodeposition*, July 30, 1986.

25. SAE J 403, *Chemical Compositions of SAE Carbon Steels-Supersedes Ford ESN-M1A46-A*, November 1, 2001.

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Appendix A

MECHANITE 19 AND TCP COMPATIBILITY

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MEMORANDUM

From: R312DS (D. Sorensen)
To: E213K (H. Archer)
Via: R312

Subj.: DSC/TGA THERMAL COMPATIBILITY TESTING OF MECHANITE 19 WITH CONVERSION COATINGS

Ref: (a) Lab Reference 200039569, Mechanite 19
(b) Lab Reference 200039570, Cr (III) based conversion coating
(c) Lab Reference 200039571, Cr (VI) based conversion coating
(d) NATO STANAG #4147
(e) CPIA Publ. 597, (1993) 301. "Compatibility of Energetic Materials by DSC and TG"

Enc: Nineteen thermal curves

1. Summary

Per your request, Differential scanning calorimetry (DSC), and Thermogravimetric Analysis (TGA) thermal compatibility testing was performed on the admixtures of Mechanite 19, ref (a), with two conversion coatings, ref (b) and (c). By the methods used, both conversion coatings are considered compatible via the methods used.

2. General Information on Compatibility

Under guidelines developed in ref (d) and (e), the definition of compatibility here is in terms of the relative predictive shelf life of the energetic component in intimate contact with another material. Thermal compatibility as determined by DSC or TGA involves running components individually and as admixtures. In DSC curves, the major decomposition peak is measured for the individual sample components and is compared with the major decomposition peak of the admixture. The greater the shift to lower temperatures for the admixture is the greater the degree of incompatibility between the ingredients. Reference (e) further develops the temperature shift guidelines per Table 1 to assess the degree of incompatibility in an admixture. It does not address changes to the Thermomechanical properties of the inert material, such as adhesive properties.

Degree of Incompatibility	**DSC Peak Temperature Shift (°C)**	**TGA Change in Weight % (%mixtures- %ingred)**
None	0-4	0-4
Slight	5-9	5-9
Small	10-19	10-19
Moderate	20-29	20-29
Large	≥ 30	≥ 30

3. DSC Analyses

All DSC analyses were performed on the TA Instruments Model 2910 after calibration against indium and zinc standards. The samples were run with a 50ml/min nitrogen purge at heating rates of 5°C/minute. Hermetically sealed aluminum pans were used in these tests. Hermetic pans are used since most

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weapon systems are sealed, simulating the worst-case scenario. Only single runs were used. In both cases, there was a <4°C change upon adding the conversion coating to the energetic, so both conversion coatings are considered compatible via DSC.

Summary Table of DSC Compatibility Data at Heating Rate of 5°C/minute.

Sample	Exotherm Peak Temperature	Compatible
Mechanite 19	197.6°	
Cr (III) coating	No apparent rxn	
Cr (VI) coating	No apparent rxn	-
Mechanite 19 + Cr (III) coating	195.6°	<4°, Yes
Mechanite 19 + Cr (VI) coating	197.9°	<4°, Yes.

4. TGA Analyses

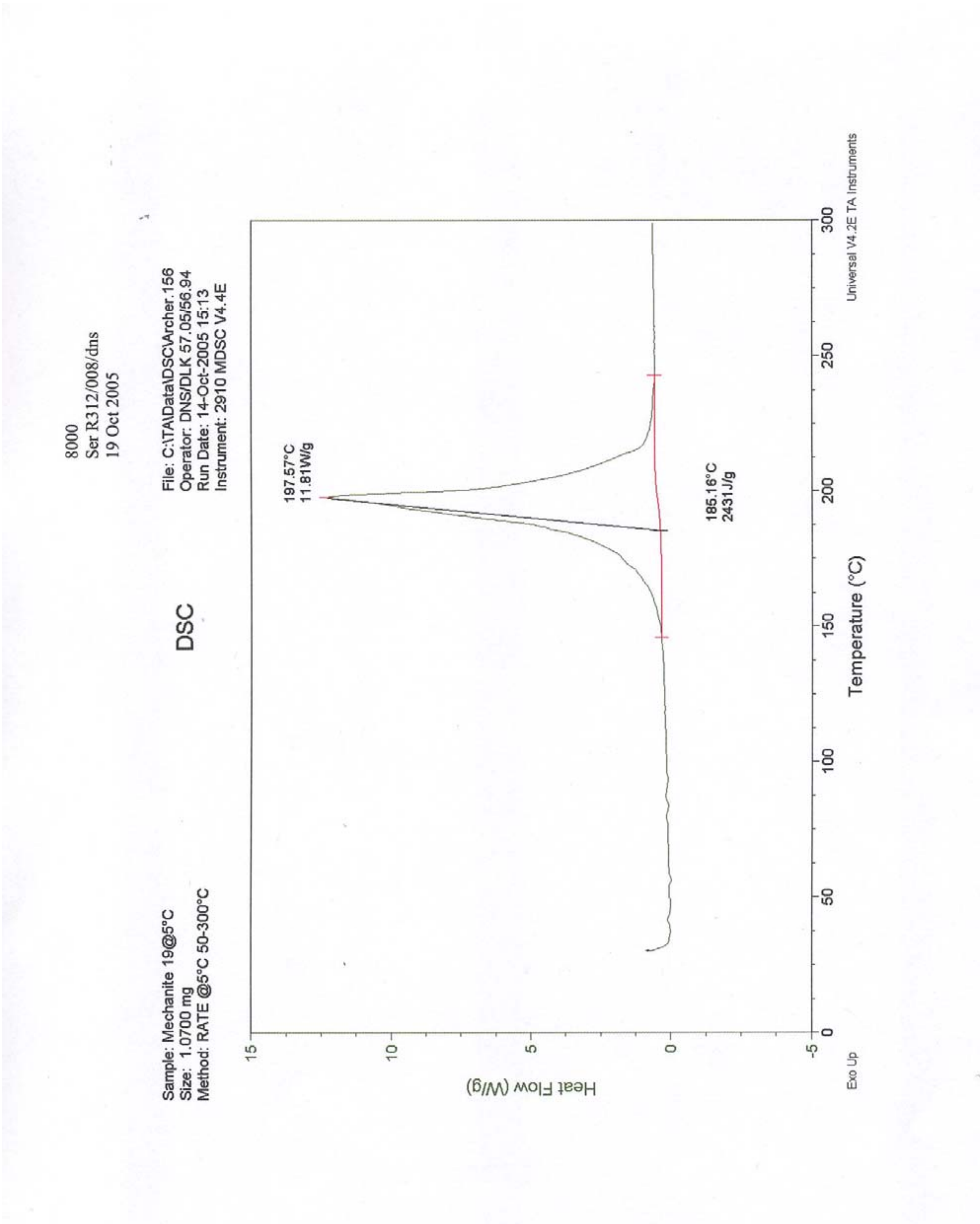
Since two methods of determining compatibility are recommended per reference (d), TGA was also performed. All analyses were performed on the TA Instruments Model 2950. The samples were run with a 50ml/min nitrogen purge at heating rates of 5°C/minute. Pin-holed aluminum pans were used in these tests. In both cases, the first weight loss peaks circa 193°. The expected contributions from the isolated materials are larger than for the Cr(VI) admixture, so the admixture is compatible. For the Cr(III) admixture, the difference is negligible, so this admixture is deemed compatible as well.

Summary Table of TGA Compatibility Data at Heating Rate of 5°C/minute, 25:75 Ratios.

Sample	Temperature Region	% Wt loss	Compatible
Mechanite 19	50-192.34°, 50-195.33°	-45.47%, -50.26%	
Cr (III) coating	50-195.33°	0.45%	-
Cr (VI) coating	50-192.34°	1.01%	-
Mechanite 19 + Cr (III) coating	50-195.33°	-21.99%	Cf. –25.17%, Yes
Mechanite 19 + Cr (VI) coating	50-192.34°	-22.7%	Cf. –22.4%, Yes

5. Debra L. Knott assisted with the data collection. Please address any questions to the undersigned at extension 4671.

Daniel N. Sorensen, Ph.D.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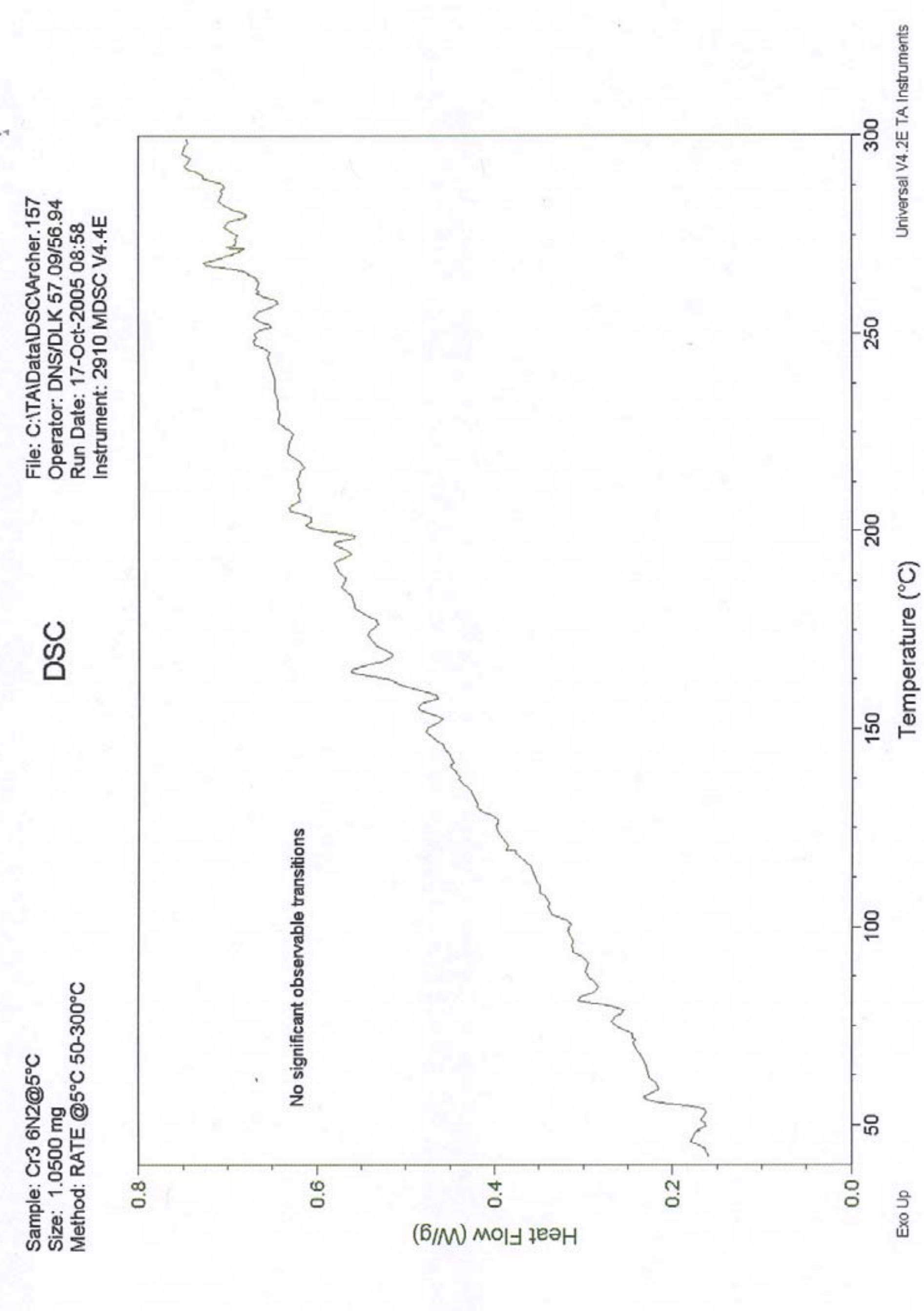
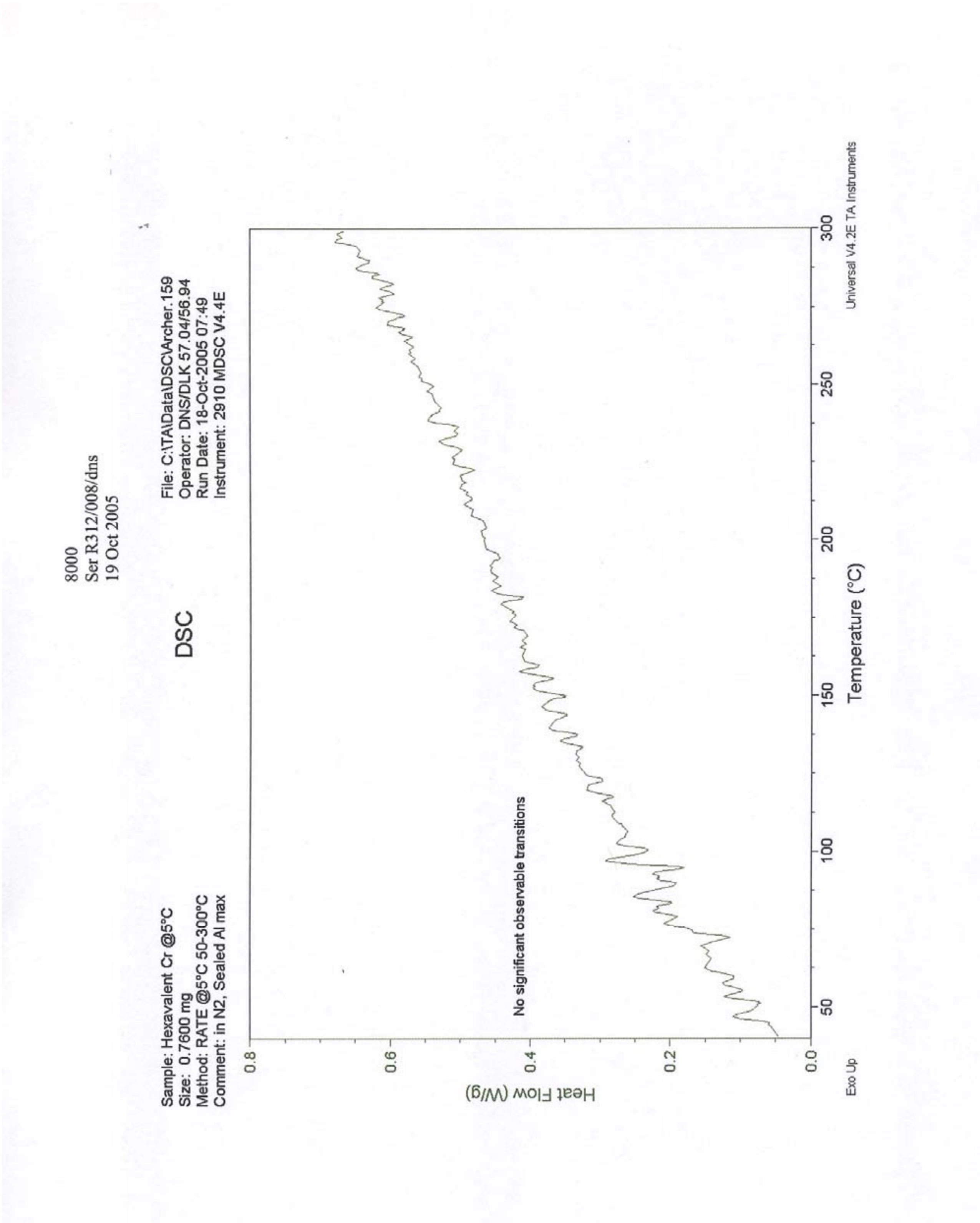
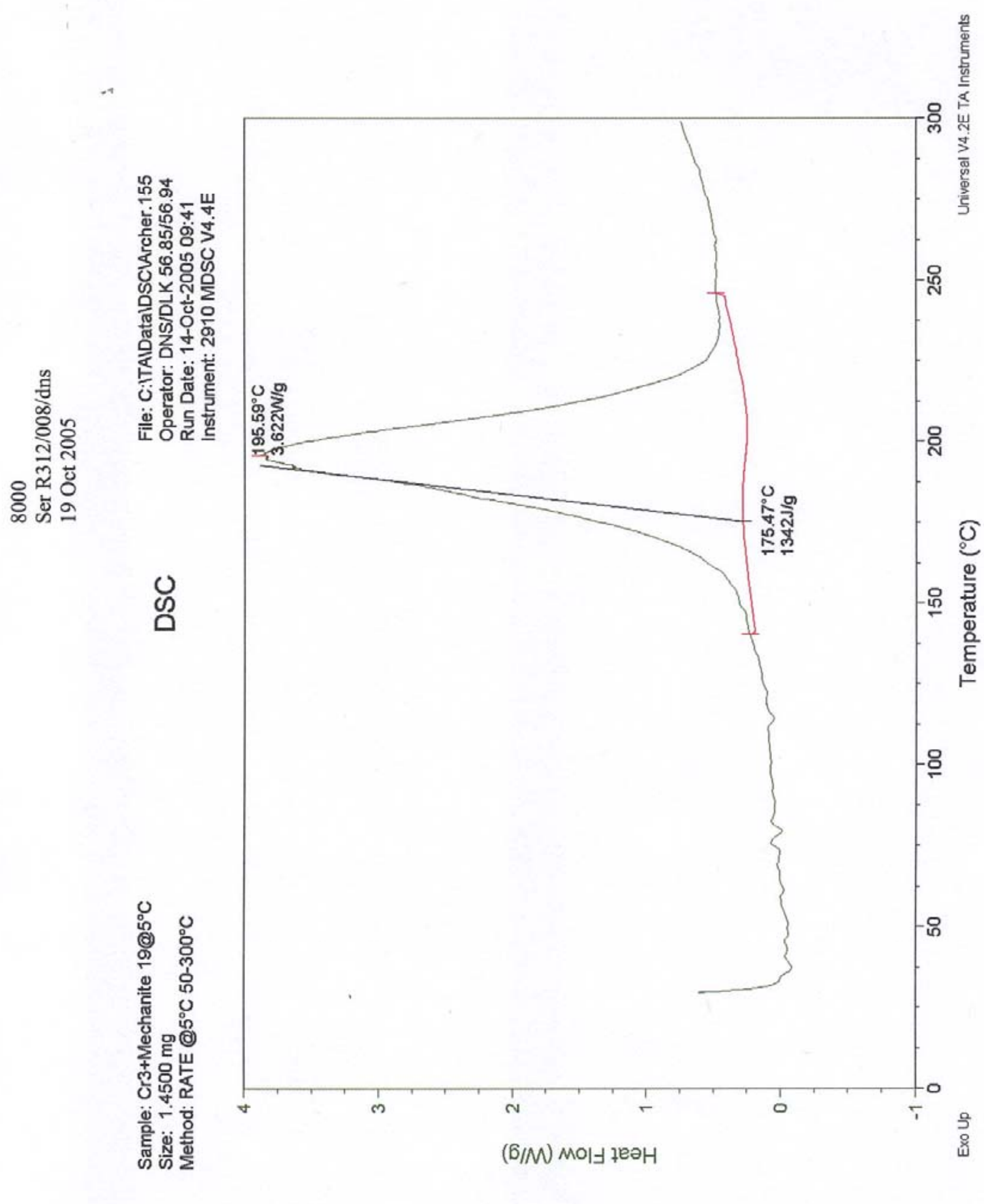
19 Oct 2005
DSC
Sample: Mechanite 19@5°C
Size: 1.0700 mg
Method: RATE @5°C 50-300°C
File: C:\TA\Data\DSC\Archer.156
Operator: DNS/DLK 57.05/56.94
Run Date: 14-Oct-2005 15:13
Instrument: 2910 MDSC V4.4E
197.57°C
11.81W/g
185.16°C
2431J/g
Heat Flow (W/g)
15
10
5
0
-5
Exo Up
0
50
100
150
200
250
300
Temperature (°C)
Universal V4.2E TA Instruments


Sample: Cr3 6N2@5°C
Size: 1.0500 mg
Method: RATE @5°C 50-300°C
DSC
8000
Ser R312/008/dns
19 Oct 2005
File: C:\TA\Data\DSC\Archer.157
Operator: DNS/DLK 57.09/56.94
Run Date: 17-Oct-2005 08:58
Instrument: 2910 MDSC V4.4E
No significant observable transitions
Heat Flow (W/g)
Temperature (°C)
Exo Up
Universal V4.2E TA Instruments


Sample: Hexavalent Cr @5°C
Size: 0.7600 mg
Method: RATE @5°C 50-300°C
Comment: in N2, Sealed Al max
8000
Ser R312/008/dns
19 Oct 2005
DSC
File: C:\TA\Data\DSC\Archer.159
Operator: DNS/DLK 57.04/56.94
Run Date: 18-Oct-2005 07:49
Instrument: 2910 MDSC V4.4E
No significant observable transitions
Heat Flow (W/g)
0.8
0.6
0.4
0.2
0.0
50
100
150
200
250
300
Temperature (°C)
Exo Up
Universal V4.2E TA Instruments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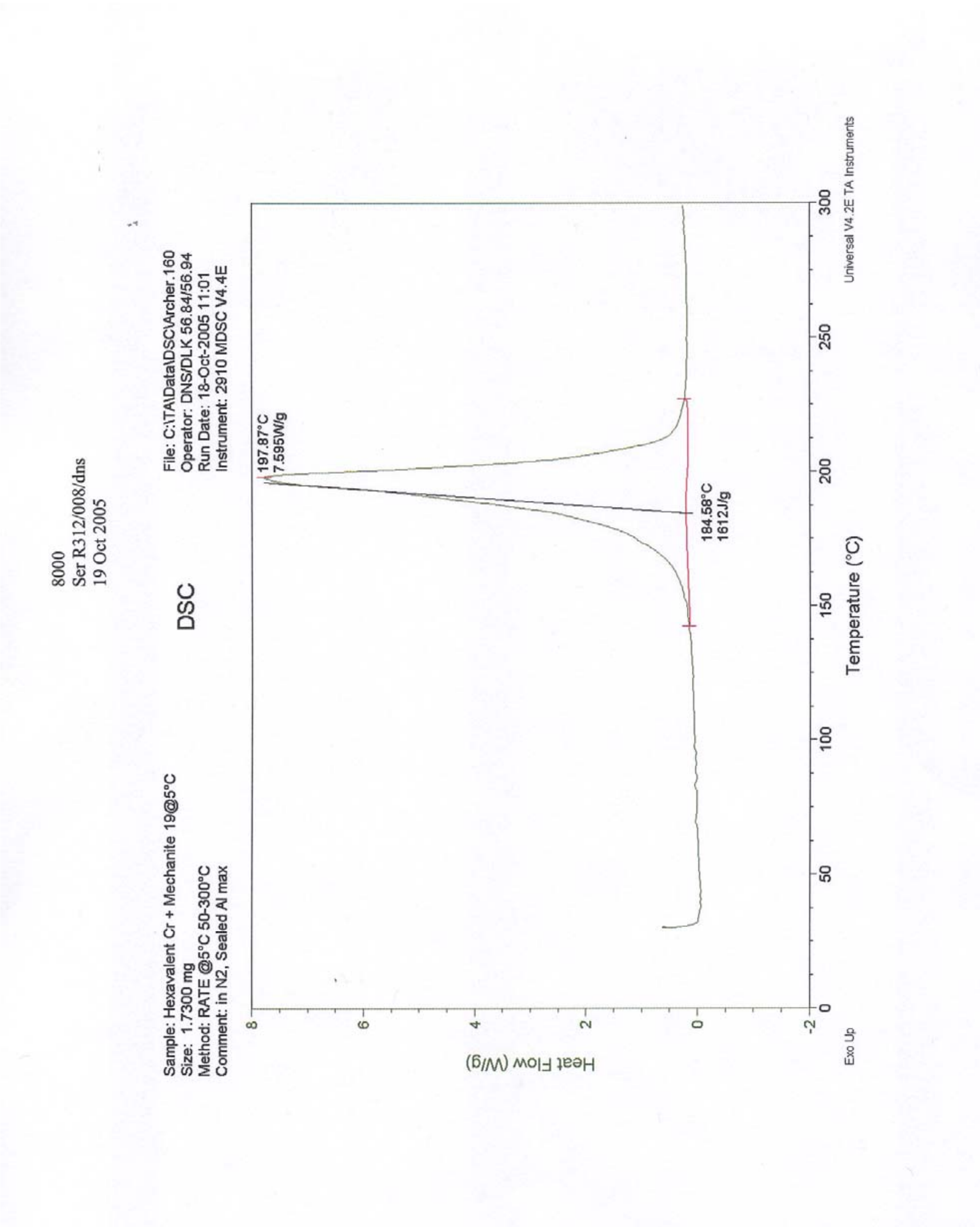
19 Oct 2005
DSC
Sample: Cr3+Mechanite 19@5°C
Size: 1.4500 mg
Method: RATE @5°C 50-300°C
File: C:\TA\Data\DSC\Archer.155
Operator: DNS/DLK 56.85/56.94
Run Date: 14-Oct-2005 09:41
Instrument: 2910 MDSC V4.4E
195.59°C
3.622W/g
175.47°C
1342J/g
Heat Flow (W/g)
Temperature (°C)
Exo Up
Universal V4.2E TA Instruments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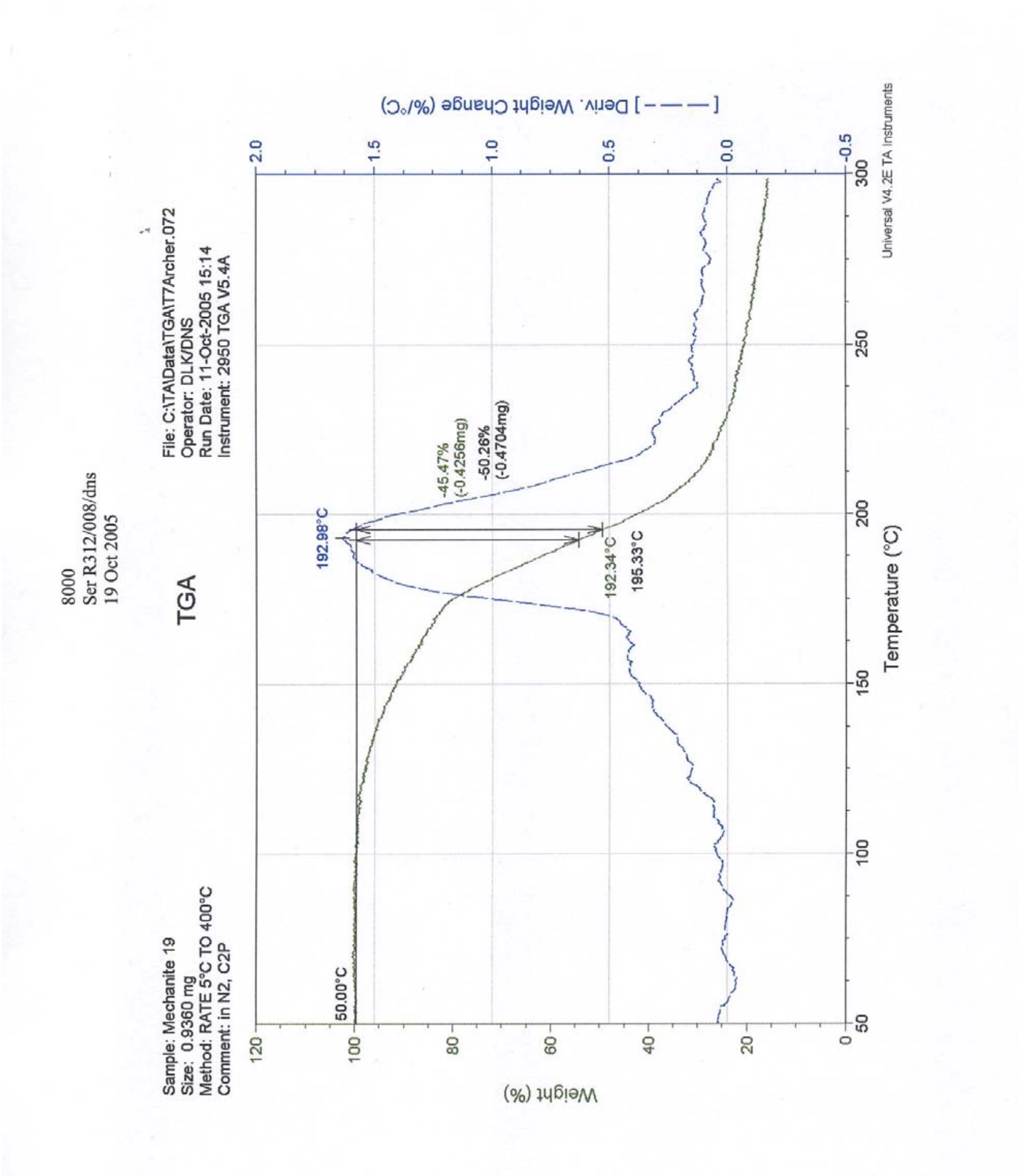
Ser R312/008/dns
19 Oct 2005
Sample: Hexavalent Cr + Mechanite 19@5°C
Size: 1.7300 mg
Method: RATE @5°C 50-300°C
Comment: in N2, Sealed Al max
DSC
File: C:\TA\Data\DSC\Archer.160
Operator: DNS/DLK 56.84/56.94
Run Date: 18-Oct-2005 11:01
Instrument: 2910 MDSC V4.4E
197.87°C
7.595W/g
184.58°C
1612J/g
Heat Flow (W/g)
Exo Up
Temperature (°C)
Universal V4.2E TA Instruments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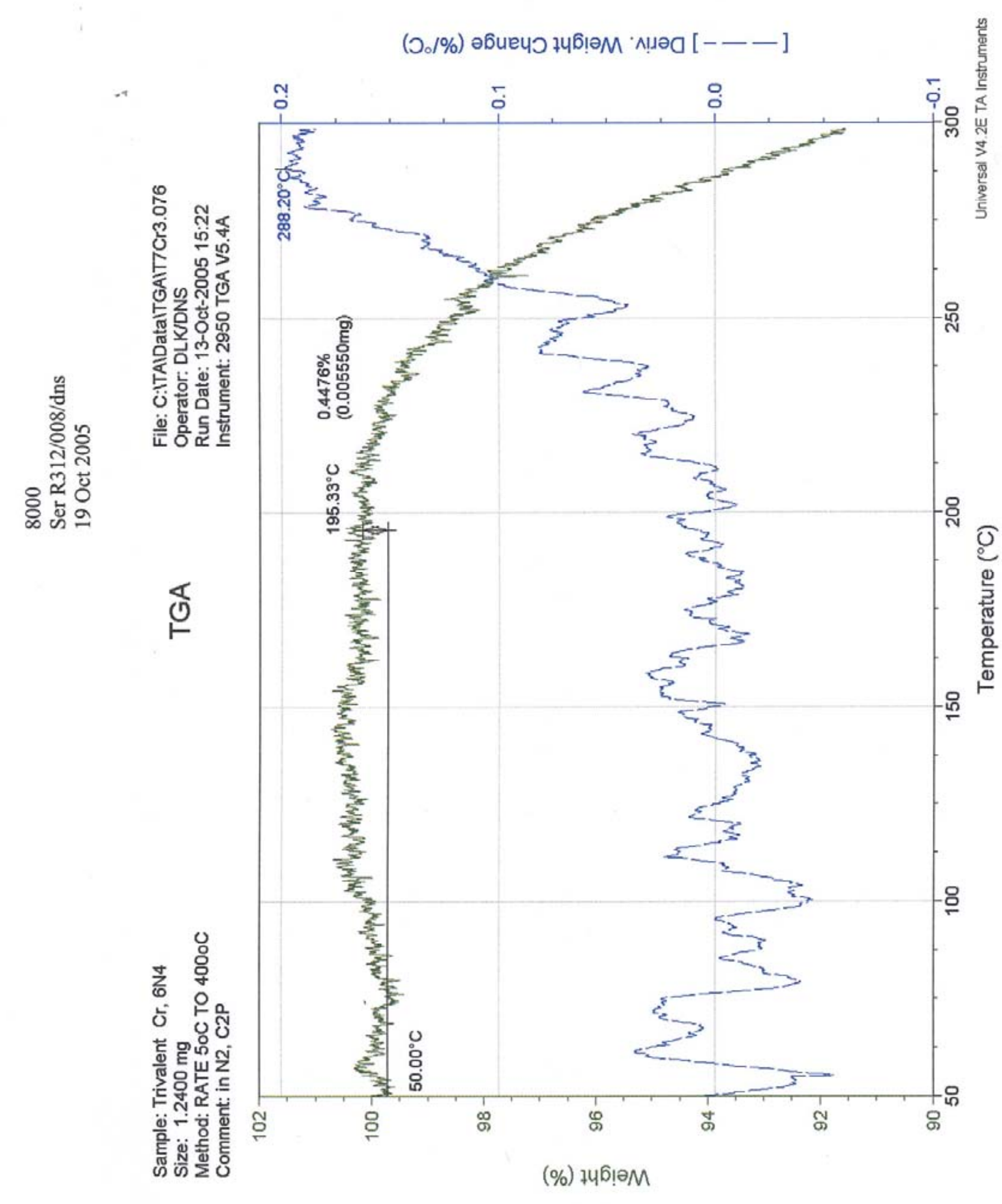
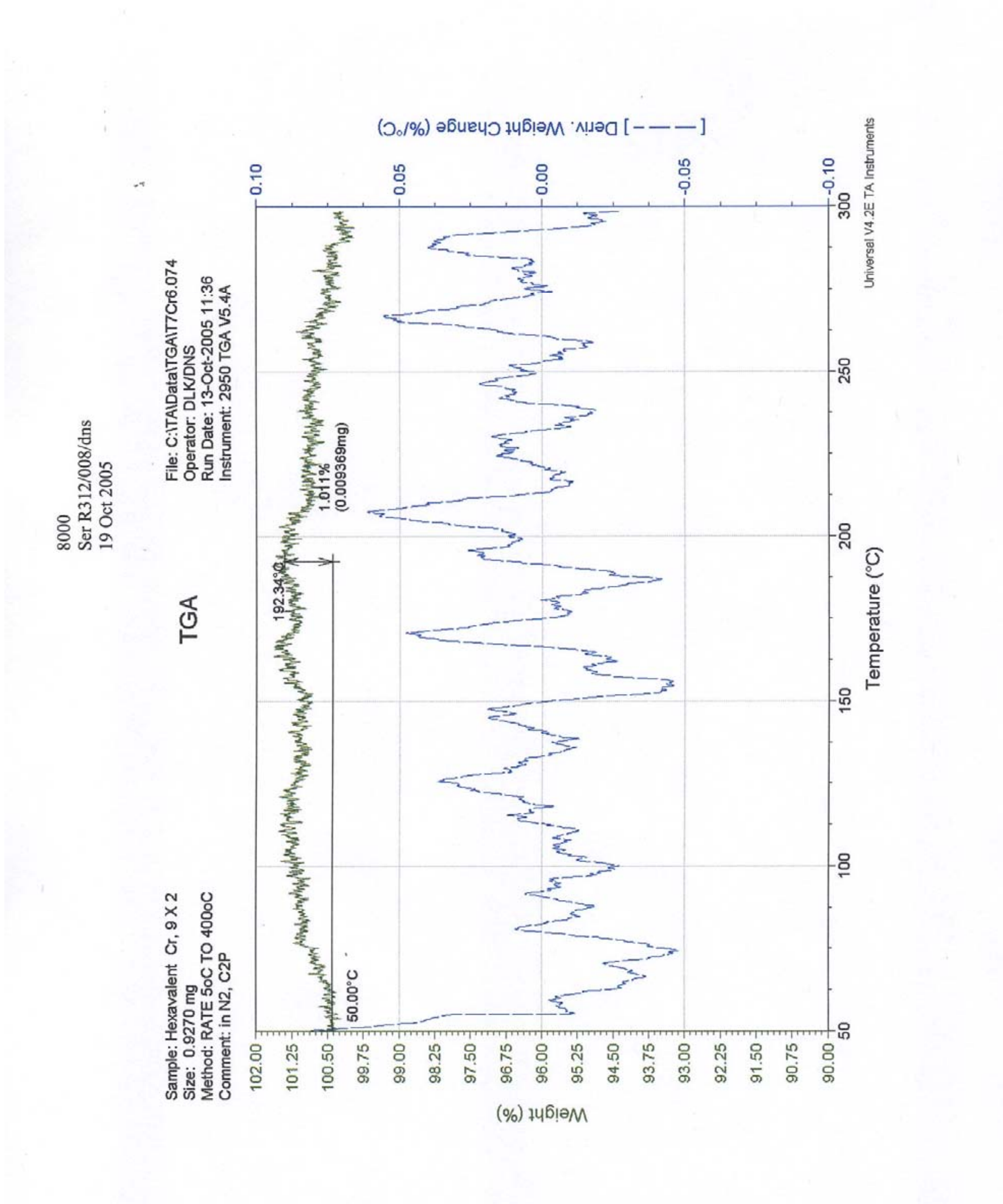
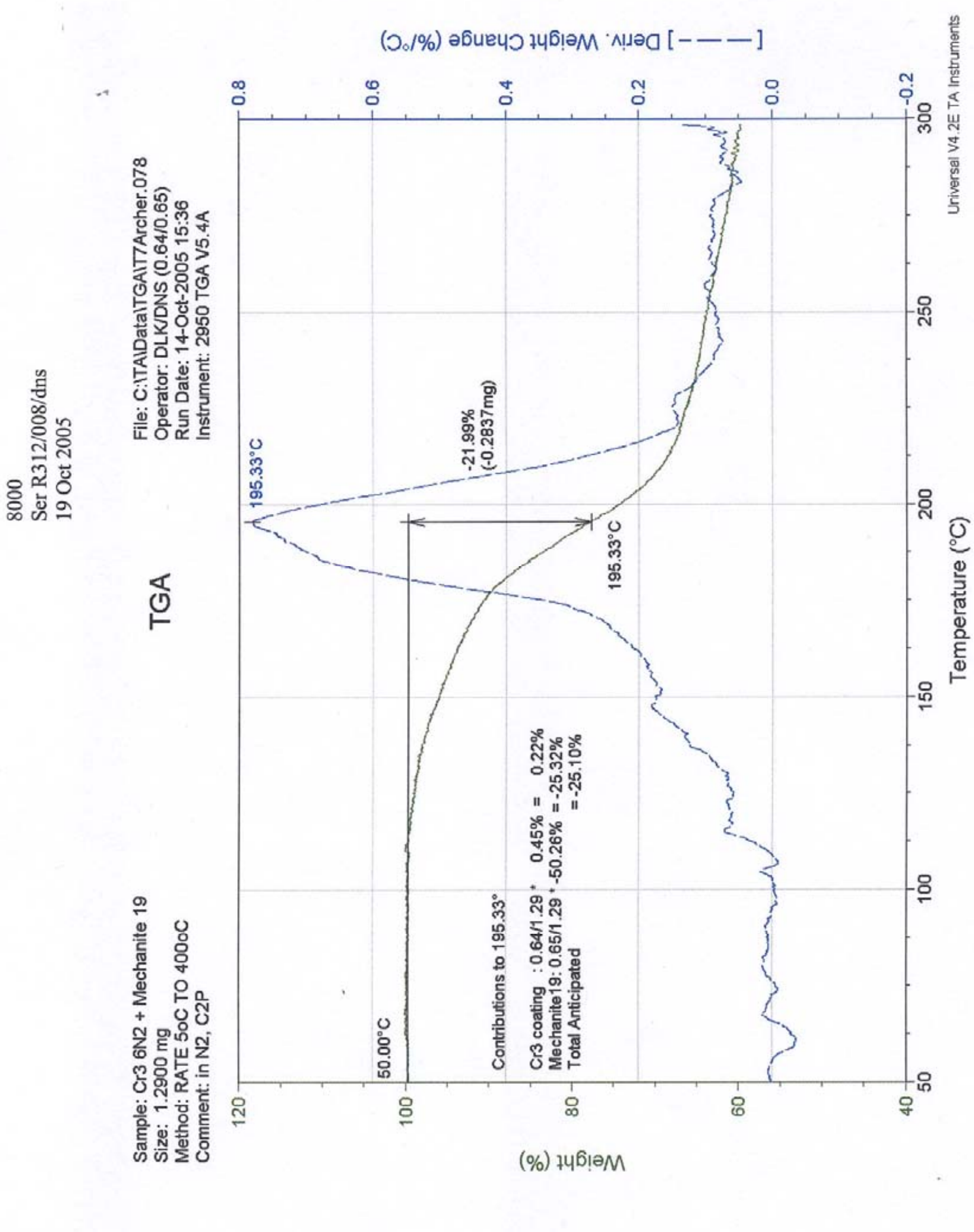
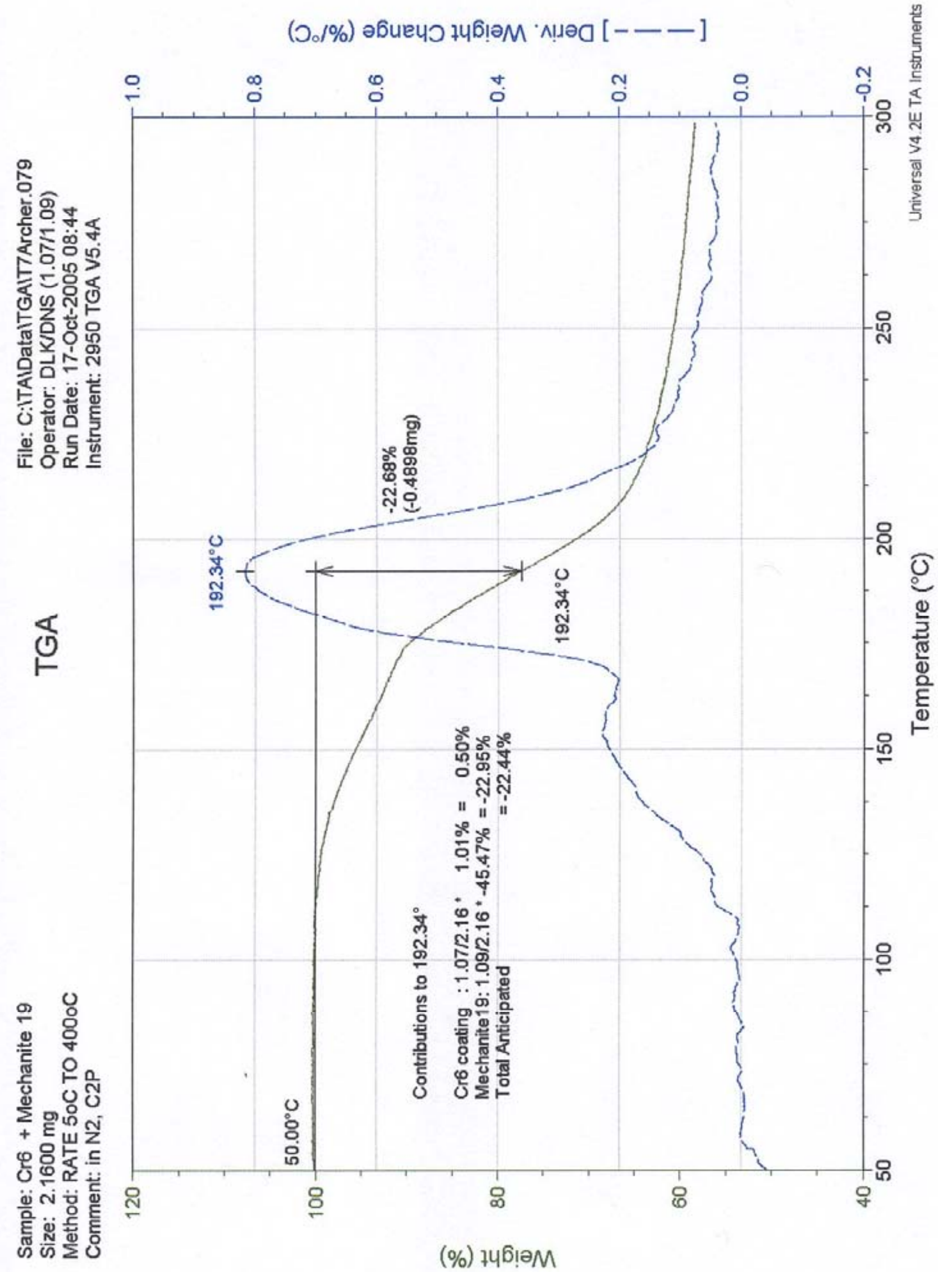
19 Oct 2005
TGA
Sample: Mechanite 19
Size: 0.9360 mg
Method: RATE 5°C TO 400°C
Comment: in N2, C2P
File: C:\TA\Data\TGA\T7Archer.072
Operator: DLK/DNS
Run Date: 11-Oct-2005 15:14
Instrument: 2950 TGA V5.4A
50.00°C
192.98°C
-45.47%
(-0.4256mg)
-50.26%
(-0.4704mg)
192.34°C
195.33°C
Weight (%)
[— —] Deriv. Weight Change (%/°C)
Temperature (°C)
Universal V4.2E TA Instruments


8000
Ser R312/008/dns
19 Oct 2005
TGA
Sample: Trivalent Cr, 6N4
Size: 1.2400 mg
Method: RATE 5oC TO 400oC
Comment: in N2, C2P
File: C:\TA\Data\TGA\T7Cr3.076
Operator: DLK/DNS
Run Date: 13-Oct-2005 15:22
Instrument: 2950 TGA V5.4A
50.00°C
195.33°C
0.4476%
(0.005550mg)
288.20°C
Weight (%)
Temperature (°C)
[— —] Deriv. Weight Change (%/°C)
Universal V4.2E TA Instruments


8000
Ser R312/008/dns
19 Oct 2005
TGA
Sample: Hexavalent Cr, 9 X 2
Size: 0.9270 mg
Method: RATE 5oC TO 400oC
Comment: in N2, C2P
File: C:\TA\Data\TGA\T7Cr6.074
Operator: DLK/DNS
Run Date: 13-Oct-2005 11:36
Instrument: 2950 TGA V5.4A
50.00°C
192.34°C
1.011%
(0.009369mg)
Weight (%)
Temperature (°C)
[— —] Deriv. Weight Change (%/°C)
Universal V4.2E TA Instruments


8000
Ser R312/008/dns
19 Oct 2005
Sample: Cr3 6N2 + Mechanite 19
Size: 1.2900 mg
Method: RATE 5oC TO 400oC
Comment: in N2, C2P
TGA
File: C:\TA\Data\TGA\T7Archer.078
Operator: DLK/DNS (0.64/0.65)
Run Date: 14-Oct-2005 15:36
Instrument: 2950 TGA V5.4A
50.00°C
Contributions to 195.33°
Cr3 coating : 0.64/1.29 * 0.45% = 0.22%
Mechanite19: 0.65/1.29 * -50.26% = -25.32%
Total Anticipated = -25.10%
195.33°C
-21.99%
(-0.2837mg)
195.33°C
Weight (%)
120
100
80
60
40
[— —] Deriv. Weight Change (%/°C)
0.8
0.6
0.4
0.2
0.0
-0.2
50
100
150
200
250
300
Temperature (°C)
Universal V4.2E TA Instruments


8000
Ser R312/008/dns
19 Oct 2005
TGA
Sample: Cr6 + Mechanite 19
Size: 2.1600 mg
Method: RATE 5oC TO 400oC
Comment: in N2, C2P
File: C:\TA\Data\TGA\T7Archer.079
Operator: DLK/DNS (1.07/1.09)
Run Date: 17-Oct-2005 08:44
Instrument: 2950 TGA V5.4A
50.00°C
192.34°C
192.34°C
-22.68%
(-0.4898mg)
Contributions to 192.34°
Cr6 coating : 1.07/2.16 * 1.01% = 0.50%
Mechanite19: 1.09/2.16 * -45.47% = -22.95%
Total Anticipated = -22.44%
Weight (%)
[— —] Deriv. Weight Change (%/°C)
Temperature (°C)
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